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TRANSPORTATION SYSTEM AND TRAVEL BEHAVIOR PROJECT RESEARCH PLAN

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The BART Impact Program is a comprehensive, policy-oriented study and evaluation of the impacts of the San Francisco Bay Area's new rapid transit system (BART).

The program is being conducted by the Metropolitan Transportation Commission, a nine-county regional agency established by state law in 1970.

The program is financed by the U. S. Department of Transportation, the U. S. Department of Housing and Urban Development, the National Science Foundation, and the California Department of Transportation. Management of the Federally-funded portion of the program is vested in the U. S. Department of Transportation.

The BART Impact Program covers the entire range of potential rapid transit impacts, including impacts on traffic flow, travel behavior, land use and urban development, the environment, the regional economy, social institutions and life styles, and public policy. The incidence of these impacts on population groups, local areas, and economic sectors will be measured and analyzed. The benefits of BART, and their distribution, will be weighed against the negative impacts and costs of the system in an objective evaluation of the contribution that the rapid transit investment makes toward meeting the needs and objectives of this metropolitan area and all of its people.

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RESEARCH PLAN

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U.S. DEPARTMENT OF TRANSPORTATION

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16. Abstract

The Transportation System and Travel Behavior (TSTB) Project of the BART Impact Program will assess the impacts of BART upon the characteristics and performance of the Bay Area transportation system--including BART, parallel and complementary transit services, and the highway system--and the responses of travelers to BART and related transportation system changes, including traveler perceptions, attitudes, and behavior. This report provides a strategic Research Plan for the entire TSTB Project. It includes discussion of a conceptual framework of the impacts processes, the major research questions to be addressed, the priorities for the research, the research methods, and finally, the major work elements of the TSTB Project.

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TRANSPORTATION SYSTEM AND TRAVEL BEHAVIOR PROJECT
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TRANSPORTATION SYSTEM AND TRAVEL BEHAVIOR PROJECT

BART IMPACT PROGRAM

DOCUMENT NUMBER PD 14-3-75
PREPARED BY PEAT, MARWICK, MITCHELL & CO.
UNDER CONTRACT WITH THE METROPOLITAN TRANSPORTATION COMMISSION
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PLANNING ASSISTANCE, AND URBAN MASS TRANSPORTATION ADMINISTRATION
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BAY AREA RAPID TRANSIT SYSTEM

PEAT, MARWICK, MITCHELL & CO.
SAN FRANCISCO

PREFACE

This report is a strategic plan for the three-year Transportation System and Travel Behavior (TSTB) Project of the BART Impact Program. It provides a conceptual framework within which each of the individual data acquisition, analysis, or interpretation activities conducted by the TSTB Project can be related. Details on individual TSTB Project research activities have been omitted to maintain the continuity and structure of this document. These details are contained in three additional documents which complement this report:

- The Detailed Research Plan* discusses, in-depth, major research issues which are only briefly addressed in this document. The Detailed Research Plan also details the Phase I TSTB Project activities.

- Working notes will describe specific data acquisition, analysis, or interpretation activities in significantly more detail than possible within the Summary or Detailed Research Plans. Working notes will only be prepared immediately prior to the actual conduct of an activity. Therefore, these working notes will serve as detailed mini-research plans for specific project activities and will reflect the findings and conclusions of prior activities in the TSTB Project.**

---

*Detailed Research Plan, Transportation and Travel Behavior Project, Document Number PD-10-1-75, prepared by Peat, Marwick, Mitchell & Co., Burlingame, California, for the Metropolitan Transportation Commission, Berkeley, California, October 1974.

**To date, the following working notes have been prepared by the TSTB Project:

1. "Special Study to Assess the Impact of the AC Transit Strike on BART"

2. "Assessment of the Immediate Impacts of BART Transbay Service"

3. "Description of Transportation System Inventory"

4. "Design of the Spring 1975 Telephone Survey"

5. "Design of the Spring 1975 Traffic Count Program"

6. "BART Cost Analysis"

7. "BART Energy Analysis"

8. "Phase I Mobility Analysis"

9. "Design of Spring 1975 Highway Travel Time Surveys"

- Annual work plans describing the tasks to be performed in each year and their associated schedules and budgets.*

The authors of this plan would like to thank Dr. Gordon Shunk, Dr. Henry Bain, and Mr. Joel Markowitz of the Metropolitan Transportation Commission for their constructive contributions and guidance in completing this effort. While sincerely appreciating these contributions, the authors acknowledge their responsibility for the content of this report.

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*Phase I Work Plan, Transportation System and Travel Behavior Project, Document Number PD-2-3-74 prepared by Peat, Marwick, Mitchell & Co., Burlingame, California, for the Metropolitan Transportation Commission, Berkeley, California, July 1974.

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I. INTRODUCTION

The BART Impact Program

In recent years, there has been a resurgence of interest in public transportation as an approach to alleviating urban transportation, environmental, and energy problems. As a result, political leaders, citizens, and professional planners at all levels of government are seeking sound data and information on the costs and benefits of rail rapid transit investments and the impacts of such investments on the communities where they are made. Inasmuch as BART is the first areawide rail rapid transit system to be planned, designed, constructed, and opened to revenue service in the United States in 50 years, it provides an excellent opportunity for satisfying these information requirements. A brief description of BART is provided in Appendix A for those readers who are not familiar with the system.

BART Impact Program Goals and Objectives. The overall goal of the BART Impact Program is to develop a clearer understanding of (1) the relationships between public transportation and other elements of community development, and (2) the costs and benefits of public transportation, specifically rail rapid transit.[1*] The overall program goal translates into the major objectives of the BART Impact Program and the TSTB Project to study the what, who, why, and how of BART's impacts.

- What--Physically measure, quantify, and document what the impacts of the BART system are on travel patterns, economy, environment, land use patterns, and life styles in the San Francisco region.

- Who--Assess the incidence of BART's impacts upon various groups of Bay Area residents to determine who is being affected by BART.

- Why--Determine, explain, and document why these impacts have taken place and test the causal relationship theory. Of equal interest is why some anticipated impacts did not occur or occurred in a lesser or different way than anticipated.

- How--Determine and document how this knowledge can be used to improve the planning, design, and operation of transit systems (and cities themselves for that matter) in San Francisco and other urban areas. Determine and document how this knowledge

---

*Superscript numbers refer to references listed in Appendix C.

might improve federal, state, and local policy-making regarding transportation and related matters.

Organization of the BART Impact Program. To achieve the objective of resolving these issues, the BART Impact Program is structured as a comprehensive program divided into six major project areas. These are:

- Transportation System and Travel Behavior
- Environment
- Land Use and Urban Development
- Economics and Finance
- Institutions and Life Styles
- Public Policy

Fundamental Considerations To Be Addressed by the TSTB Project

At present, many metropolitan areas within the United States are proposing, planning, or implementing rail rapid transit systems. In each of these communities, a number of questions have been raised concerning the relative costs and benefits of rail rapid transit investments and the impacts of these investments upon the community. In terms of the TSTB Project, it is possible to organize these various questions into three broad categories of considerations:

- Impacts of rail rapid transit on traveler perceptions, attitudes, and behavior and travel patterns.
- Transportation policy considerations related to the planning, design, operation, and financing of rail rapid transit systems.
- Social and equity considerations associated with rail rapid transit.

As far as possible, the TSTB Project must provide findings and conclusions on the various questions comprising these crucial considerations. The extent to which the findings of the TSTB Project are transferable to rail transit policy and planning decisions elsewhere depends, among other factors, upon:

- The extent to which the conclusions are a function of the specific geography, urban form, and economy of the Bay Area.
- The extent to which the high initial development and start-up costs of BART have influenced the "cost side" of the assessment of costs and benefits.

Changes in Traveler Perceptions, Attitudes, and Behavior and Travel Patterns Resulting from BART. Within the first consideration are questions pertaining to the extent to which BART results in a more transit-oriented travel pattern within the community and a consequent reduction in automobile travel. These questions are of considerable importance because if BART were to result in a more transit-oriented and less automobile-oriented travel pattern, there would be a number of important benefits, including:

- Traffic congestion would be reduced on highways in the BART corridors. This was one of the principal benefits of BART cited by its proponents during the initial planning stages.[2]

- There would be a reduced need for expensive investments in automobile facilities, particularly highway and parking projects. This was another major benefit of BART which was noted by its advocates during the planning stages.[2]

- Energy consumption (and especially gasoline consumption) would be reduced. This anticipated benefit of rail rapid transit is frequently cited by current proponents, although it was not mentioned by those who advocated the construction of BART.[3]

- Air pollution would be reduced. This is another benefit frequently cited by current proponents of rail rapid transit, although it was not emphasized by those who advocated the construction of BART.[3]

- The attraction of ridership to BART would allow for a more financially viable operation of the urban transit system. Inasmuch as public transit is essentially a public sector activity, this issue is of major concern to those associated with financing public transportation at the federal, state, and local levels.

The broad consideration of the extent to which BART results in a greater reliance upon transit as opposed to automobile travel, can be divided into two specific questions:

- Has BART caused short-run travel behavior changes including a diversion of travel from automobile to transit?

- Will BART cause long-run changes in the total quantity of travel and its geographic distribution?

It has been hypothesized that modal diversions occur because BART offers a more attractive level of service relative to the automobile and the existing bus transit system, thereby improving travelers' attitudes toward transit. It has also been hypothesized that long-run changes occur as a result of

the differential increases in land development at locations with significantly improved accessibility resulting from BART (particularly the central business districts (CBD) of Oakland and San Francisco and those suburban areas with sufficient vacant land for the construction of large new housing developments.

Transportation Policy Considerations. The transportation policy considerations pertain to an assessment of the total benefits and costs and, thus, the effectiveness and economic efficiency of rail rapid transit technology. This assessment compares rail rapid transit to other existing or potential transit technologies and considers the individual system components of the rail rapid transit technology.

The principal alternative technologies which are currently of interest to transportation decision-makers include:

- Express- and reserved-lane bus options
- Low capital investment options such as car pooling and staggered work hours
- Low cost light rail technologies
- Personal Rapid Transit (PRT) technologies
- Highway and private automobile-oriented options

While the TSTB Project can attempt an after-the-fact assessment of the benefits and costs of BART, it cannot perform a similar comparison for the other options. These can be quantified only through a conventional planning exercise, although the improved planning methodologies developed by the TSTB Project could be used in the exercise.

The BART experience in the Bay Area has important implications for the planning and design of many important features of rail rapid transit systems which are being considered or implemented in other metropolitan areas in the country. Thus, it is important to assess the benefits and costs associated with each of the specific design and operating features of BART. Among these are:

- The line configuration of the system and its effects on train operations
- The availability of cars to provide passenger carrying capacity
- The spacing of stations
- The fare structure

- The provision of parking facilities at stations

- The level of feeder bus service to BART stations

- The comfort of the BART cars (e.g., seat size, carpeting, air-conditioning, and tinted windows)

- The degree of automation in ticketing and the provision for prepayment of transit fares

- The automation of the train control system and the consequent impacts upon labor productivity and operating costs

- The automation of the train control system as it affects safety and reliability

- The security features such as police services, lighting, and station attendants

- The safety aspects of the control system, the cars, and the stations

- The provision of elevators and other special facilities for physically handicapped travelers

- The design of the system as it affects capital and operating costs

Social and Equity Considerations. The social and equity considerations related to BART concern the incidence of benefits and costs among various groups of Bay Area residents, particularly by disadvantaged residents. With respect to the social benefits of BART, the major questions are whether BART has increased the mobility of certain disadvantaged groups by, for example:

- Providing improved access to higher paying jobs for those who are relatively poorly paid, the unemployed, and ethnic minorities.

- Improving access to health care facilities.

- Providing improved access to educational facilities.

- Improving access to public and private service organizations.

- Improving access to recreational facilities.

- Improving access to lower priced and better shopping.

- Providing mobility to a variety of activities for the elderly, handicapped, and young, and for those who do not have access to an automobile.

- Reducing the need for investment in an automobile, especially for the lower income residents of the community.

In assessing the improvements in transit accessibility and mobility provided by BART, it is also necessary to consider the implications of the reductions in bus service accompanying BART's introduction and the fact that the transit fares for BART are either equal to or greater than the corresponding fares for the bus services which were removed.

On the other side of this social consideration, the costs must be weighed in a major set of questions on whether the BART-related improvements to the mobility of disadvantaged residents are economically efficient; that is, whether BART provides the least expensive approach to achieving a given level of improvement in the mobility of the travel disadvantaged. These questions are of considerable importance, because it has been suggested that the mobility which rail rapid transit provides to disadvantaged groups could be provided more efficiently and economically by other forms of public transportation--such as improved local bus service.

The equity considerations pertain to the distribution of the benefits and the costs of BART among various segments of the population. Questions have been raised concerning whether BART's accessibility and mobility impacts are socially inequitable to the extent that they involve a transfer payment from the disadvantaged residents of the community to the more well-to-do residents. That is, are the benefits provided to disadvantaged groups in the form of improved mobility less or greater than the costs of BART which are borne by these groups in the form of higher transit fares, increased sales and property taxes, higher rents, and perhaps the disruption of their neighborhoods by BART's construction? Correspondingly, are the more prosperous segments of the community benefiting to a relatively greater extent from BART than the costs that they bear for the construction and operation of the system?

The general equity consideration of the incidence of the benefits and costs of BART among various segments of the population is of interest within the Bay Area and in other metropolitan areas.

In addition, in the Bay Area itself, there are certain specific questions relating to the geographic incidence of the benefits and costs. Since some Bay Area counties are not members of the Bay Area Rapid Transit District (BARTD) and, therefore, do not pay the property and sales taxes associated with supporting BART, it is important to assess the extent to which residents of these nonmember counties utilize BART and thereby benefit from its service. Although this situation could occur in a number of instances, it is of particular concern with respect to the residents of San Mateo County who utilize the BART line from Daly City. While this issue is of considerable

interest in the Bay Area, it is of relatively less interest to other metropolitan areas, unless they plan to implement rail rapid transit systems which do not serve an entire region.

Overview of This Report

Chapter II presents a simple conceptual model of the process whereby decisions to change the transportation system result in changes in traveler behavior and then in travel patterns. This discussion focuses on how the impedances of various transportation system components are perceived by potential travelers and how these perceptions form the basis for travel decisions. The aggregate of all these individual travel decisions is a pattern of travel on the various components of the transportation system.

To study the what, who, and why issues of BART's impacts, a series of questions concerning the magnitude and extent of BART's impacts can be structured. The formulation and testing of these questions are a central theme of the TSTB Project. The critical questions concerning the impacts of BART on the transportation system and travel behavior are presented in Chapter III, using the conceptual framework developed in Chapter II as a context.

Chapters IV, V, VI, and VII are devoted to a discussion of the research methods which will be used to develop responses to the questions identified in Chapter III and to respond to the broader why and how issues which need to be addressed by the program. Chapter IV contains a discussion of research priorities for the TSTB Project with respect to which impedances, geographic subareas, travel market segments, and potential traveler and trip characteristics will be studied.

A description of the types of analyses and research designs that will be used to answer each set of questions is presented in Chapter V. One of the most difficult problems which the TSTB Project must surmount is to distinguish between those impacts resulting from BART and those resulting from other or exogenous factors. While it is relatively straightforward to assess those changes in the transportation system and travel behavior that occurred concurrent with the introduction of BART, other factors did not remain the same. Consequently, it is necessary to devote significant effort to ascertaining the extent to which the changes in other factors can be attributed to BART. The use of control in assessing the extent to which changes can be attributed to BART is discussed in Chapter V in the context of a proposed set of quasi-experimental designs.

Chapter VI discusses the research methods to be used in explaining and interpreting BART's impacts (that is, to answer the why and how issues of the program). The principal why issue pertains to assessing the causes of BART's impacts on travel behavior. The how issue pertains to the benefits and costs of BART with respect to: (1) other system options, (2) their incidence upon particular population groups, and (3) specific BART design

features and operating characteristics. The research methods presented in Chapters IV, V, and VI, in turn, imply a set of data requirements for the TSTB Project. Chapter VII presents an integrated statement of the total data acquisition requirements of the TSTB Project. Because of the limitations of existing methodologies, special survey methods are required to assess BART's impacts on the mobility of disadvantaged groups within the Bay Area; these special survey methods are also discussed in Chapter VII.

The research methods reviewed in Chapters IV, V, and VI and the data collection activities discussed in Chapter VII will be implemented in a series of subprojects which will be conducted within the TSTB Project. Chapter VIII describes the subprojects and the relationships between these subprojects and the identified research methods and data collection requirements.

Because of the central role of travel impacts within the overall context of BART's impacts upon the Bay Area, the TSTB Project will provide data and findings to other elements of the BART Impact Program as well as other ongoing planning activities within the Bay Area. Also, the research findings of the TSTB Project will be compared to the findings of other impact studies of major transit improvements. These elements of project integration and coordination are discussed in Chapter IX of the Summary Research Plan.

II. CONCEPTUAL FRAMEWORK OF BART IMPACT PROCESSES

This chapter describes a simple conceptual framework for the process whereby BART impacts the transportation system and travel behavior within the BART service area. This framework provides the basic structure for answering the questions on BART's impact presented in Chapter III. As shown on the sketch of the framework (Exhibit 1), it is made up of six components, each representing a set of variables that are subject to definition or measurement.

The processes involved in BART's impact are initiated with decisions regarding transportation in the BART service area. These decisions relate to both BART and the complementary and competing modes. As a result of these decisions, the transportation system attributes in the BART service area are modified; and because of these attribute changes, travelers modify their perceptions of the impedances of the transit and automobile systems. Responding to the modified impedances, individual travelers adjust their short- and long-term travel behavior. Both the perceptions of the impedances by travelers and the behavior modifications resulting from these impedance changes are affected by the characteristics of both potential travelers and their potential trips. The aggregate of the changes in travel behavior of each individual traveler constitutes changes in travel patterns. Modifications in the travel patterns, in turn, influence transportation system impedances and attributes (for example, the number of travelers using a BART train influences the availability of seats). Each basic element of this simple conceptual framework is discussed in this chapter.

A--Decisions Affecting the Transportation System

Decisions relating to the technology, location, design, and operating policies of the transportation system in the BART service area are the initial stage of BART impact processes. The transportation system is conceived here as embracing all the vehicular modes of people movement within the region, plus all facilities provided for the nonvehicular portions of trips that employ vehicles at some point.

There are several transportation services either complementing or competing with BART in its overall service area including automobile, bus, streetcars, cable car, and jitney. In assessing BART's impacts, it is necessary to consider not only those decisions pertaining to BART, but also decisions pertaining to the complementary and competing modes.

Decisions Affecting Transit System Attributes. There are four types of decisions which affect transit system attributes. First, the policies of central and local government with regard to the financing of mass transit affect the attributes; that is, the levels and kinds of grants and subsidies

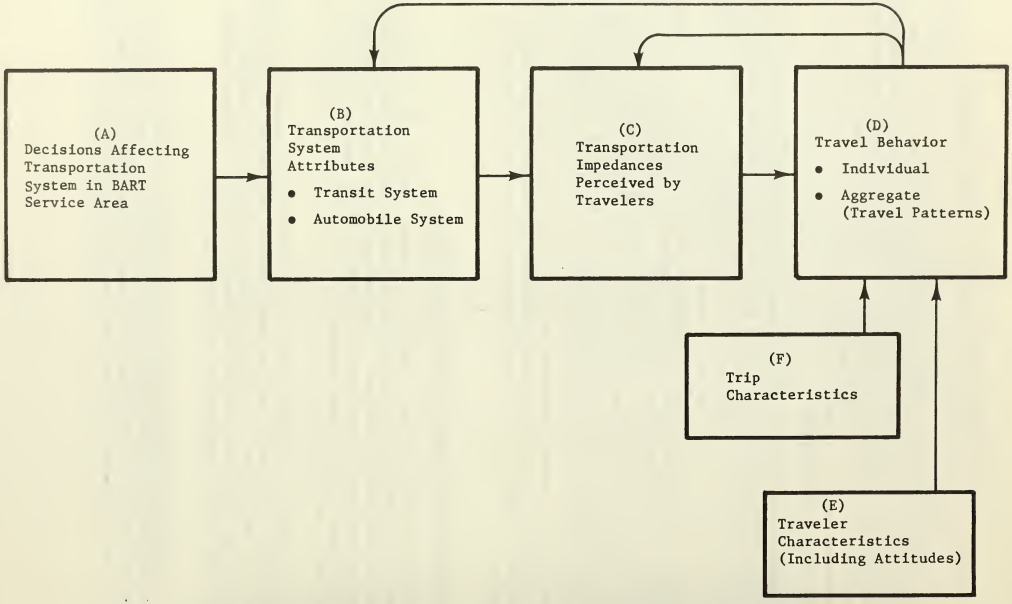

Exhibit 1
CONCEPTUAL FRAMEWORK
BART IMPACT PROCESSES

provided for both capital and operating expenses and the ability and willingness to raise funds through sales, property, and highway user taxes. Secondly, by the available technology of the transit vehicles and their control systems determine the attributes. Third, the management and operating policies of the transit operators on the provision and pricing of services affect the attributes. These operating policies are controlled, in part, by external factors over which management may have little or no control, such as the price and availability of fuel or the requirements of the State of California Public Utilities Commission for service provision and operating standards. Fourth, the traffic levels or characteristics of other components of the transportation system affect the transit system. This is particularly the case when the right-of-way of the transit mode is shared with other modes such as buses and automobiles on highways.

Decisions Affecting Automobile System Attributes. Governmental policies at the central and local levels have a major influence on the attributes of the automobile system. This influence is manifested in financial decisions regarding funding for construction of new and improved highways and the planning decisions necessary for implementation of improvement projects. Governmental decisions affect highway operations, traffic regulations, and speed limits. The presence of these influences has recently become particularly noticeable with the reduction in the nationwide speed limit to 55 miles per hour. Governmental decisions can similarly dictate the cost and availability of parking space, either through planned zoning regulations or street parking regulations. Other forms of taxation may be applied in the form of tolls for usage of particular facilities, possibly "congestion tolls" or, more simply, through vehicle licensing charges and gasoline taxes.

B--Transportation System Attributes Resulting From Decisions

Transit System. The attributes of the transit system are viewed by its operators in terms of routes, stations and terminals, equipment, schedules, supply costs, and energy consumption. The routes of both the BART and bus systems are defined by the terminal points and the station or stop locations. The attributes of the equipment used in transit service are largely a function of equipment design, which in turn is related to the equipment's age and its method of operation. The schedule of operations is determined largely by the vehicle fleet size and the availability of personnel to operate the vehicles. The schedule of vehicles running on the routes of the transit system are defined by the hours of operation and the headway between vehicles at different times of the day. A large number of cost components are of concern to the transit system operator; some of these costs are essentially fixed, while others are a function of the service level (i.e., schedule) provided, and others are a function of system ridership.

Automobile System. The automobile system can be characterized in terms of the following attributes: routes, stations and terminals, equipment,

supply costs, and energy consumption. Aside from a car pool situation, there is no schedule involved in using the automobile mode.

C--Travel Impedances Resulting From These Attributes

Impedances are defined as the service characteristics of the various transportation modes from the perspective of the traveler. A particular traveler, contemplating a particular trip, will make his travel choice with regard to different travel dimensions based on his perception of the impedances of the available travel mode options. Consequently, the starting point for analysis of travel behavior must be a definition of the different transportation mode impedances perceived by travelers and considered in their travel choices.

Traditional transportation planning analyses have tended to describe the service provided by the transportation system in terms of a relatively limited number of impedances--particularly travel time (for the various segments of a trip) and total trip cost. There is considerable evidence that a variety of other impedances have an important influence on travel behavior--particularly on the traveler's utilization of public transportation. Clearly, if every aspect of every component of the trip by all alternative modes were included, the complete list of impedances would be very long. The 30 impedances shown in Appendix B will initially be considered in the TSTB Project because:

- A review of previous research studies suggests that these 30 impedances are of particular importance in the traveler decision-making process.[4]

- It is anticipated that BART will affect these 30 impedances.

In addition to the 30 impedances, there are others that will affect public attitudes. Among these is a fear of traveling underground, particularly fear of traveling beneath the Bay in an earthquake-prone area. Other aspects of BART that will affect attitudes are the courtesy and efficiency of BART station staff and train crews and the clarity of information presented to travelers regarding use of the system. Excluding these from the list presented in Appendix B does not necessarily mean that they will not be considered in the TSTB Project analyses.

D--Travel Behavior

Individual traveler decisions are made as a function of the perceived impedance values. The summation of all such individual decisions gives rise to travel patterns, (i.e., ridership on the facilities of the transportation system). Thus, a model of how individual travelers respond to changes in the impedances of the transport alternatives available to them is crucial to understanding and assessing BART travel behavior impacts at both the disaggregate and aggregate levels (approaches to this causal model are discussed in Chapter VI).

Dimensions of Traveler Decisions. Traveler choices are made as a function of the impedances of the transit and automobile systems (the transportation supply) and the characteristics of the potential travelers and their potential trips (transportation demand). In assessing traveler choices, it should be recognized that in most cases, travel is a derived demand. That is, with few exceptions, demand for travel is a result of the desire or need to accomplish some activity at a remote location, and not a desire to travel per se. Thus, changes in the impedances of the transportation system will result in changes in the nature, frequency, and location of the activity patterns as well as changes in the travel choices for existing activity patterns.

Further, it should be recognized that there is a time dimension to the changes in traveler behavior. Whereas some changes may occur in the relatively short term (e.g., changes in mode, route, or schedule for an existing trip), other potential changes in traveler behavior may only occur in the long term (e.g., changes in automobile ownership or the location of some activity sites, particularly for work). Thus, it might be expected that given a change in travel impedances resulting from the introduction of BART service, the character of the traveler behavior changes will be different depending on the length of time following the introduction of the BART service.

In general, traveler choices are made with regard to seven dimensions of travel:

- Frequency of Travel--Trips may be made more or less frequently or even eliminated. The pattern of trip-making may be reorganized insofar as trips for different purposes may be combined into more complex trip patterns.

- Time of Travel--The scheduling of the trips may be shifted earlier or later to avoid particular travel impedances.

- Location of Activities--In the very short run, the choice of destination for shopping or recreation trips may be changed relatively easily. In the longer run, the place of employment may be changed as a response of travelers to travel impedances. In an even longer time frame, residential location may also be changed as a result of changes in relative transportation mode impedances (this last traveler response will not be considered in the TSTB Project but, rather, is a major focus of the Land Use Project).

- Mode of Travel--Changes of mode may take place in the access or line-haul portion of a trip. The change may be a "prime" modal diversion from automobile to transit or vice versa; or a "sub" modal diversion from one transit mode to another (e.g., from bus to BART) or increasing automobile occupancy (such as adopting a car pool arrangement).

- Route of Travel--The route of travel may be altered as a result of the changed travel impedances; this is particularly important for the automobile line-haul mode, although changes in bus route might also take place.

- Conduct While Traveling--The traveler's behavior during the course of the trip may be modified as a result of the changed travel impedances.

- Automobile Ownership--The number of automobiles owned by the household may be either decreased or increased as a result of changed travel impedances; this is one of the changes which would probably occur over a longer period of time.

Scale of Effect--Aggregate Travel Patterns. Through aggregation of all individual traveler decisions, and as a result of the processes of equilibration of transportation supply and demand (for example, the effects of highway traffic congestion or crowding on transit), a pattern of traffic flows arises on the links of the highway and transit network. The occupancy or loading of vehicles is the parameter linking the volumes of person-trips and vehicle-trips on the system. Thus, measurement of passengers or vehicle flows is an important indicator of the effects of changes in the impedances of any component of the transportation system with regard to the total number of trips being made, the origin-destination pattern, the route, and the mode. The variation over time of these highway and transit ridership volumes is similarly an important indicator of impact with regard to the time-of-travel dimension.

Establishment of New Equilibrium Between Transportation Supply and Demand. The processes whereby a new equilibrium between transportation supply and demand is achieved is an important, though more subtle aspect of the response to the changes in travel impedances. As noted, a new travel pattern will emerge as the aggregation of individual traveler responses (or nonresponses) to the changes in travel impedances. These changes in travel patterns may well have a secondary impact on both the attributes of the transportation system as well as the impedances. For example, a change in the usage of a transit mode will affect such impedances as the availability of seats and the degree of crowding. Also, the transit operator may modify the attributes of the service by increasing the number of vehicles. Similarly, a change in the usage of a particular highway will affect the travel time as well as the reliability of travel on that highway link. Thus, the response of the transportation system to decisions is dynamic because of the feedback loop between the changes in travel behavior and the transportation system attributes and transportation impedances perceived by travelers. It is generally believed that the dynamic aspect of the response tends to dampen over time as a new equilibrium position is achieved.

E--Characteristics of Potential Travelers

The previous discussion focused on transportation system attributes and the way that travelers perceive the impedances of the transportation system in making their choice decisions. However, the way transportation impedances are perceived and the resulting traveler behavior will vary for different travelers as a function of the circumstances in which the traveler makes the choice and his personal and socioeconomic characteristics. Together, the situational and socioeconomic characteristics are referred to here as the characteristics of potential travelers. The term "potential" is used to reflect the fact that trips are not necessarily made as a result of the travel decision.

Many traveler characteristics represent the extent to which the traveler is constrained in his travel choice. The "constraint" characteristics will be considered as those influencing the way that travelers perceive their satisfaction with the impedance of the alternative modes.* The most important of these "constraint" characteristics are automobile availability and the ability to drive (possession of a valid driver's license). Travel by transit may also make certain requirements of travelers, such as the ability to climb steps or escalators or the ability to read direction and information signs in English. The amount of money available to the traveler will influence his ability to make certain travel decisions, either in the long run with respect to the ability to own and operate an automobile, or in the short run in terms of the ability to buy gas or the transit fare for a specific trip. In a similar way, the "time budget" of a traveler will exercise a constraint on his travel choice. These time and money budgets are related through the concept of the "value of time" trade-off. Clearly, the wealth or income of the traveler is a primary determinant of these characteristics.

A second group of traveler characteristics are those influencing the way travelers attach importance to the modal impedances. These characteristics reflect such influences as the experience, education, culture, health, and personality of the traveler. Most of these characteristics are difficult to directly measure. A number of observable socioeconomic variables can be used as surrogates for these characteristics; these surrogates include sex, age, educational level, ethnic identification, income, occupation, years of residence within the metropolitan area, ability to communicate in English, physical capabilities, and possession of a valid driver's license.

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*In transportation planning literature, the terms "perception" and "attitude" are sometimes used synonymously with the concepts of "satisfaction" and "importance," respectively. This use of the terms has arisen from the notion that travelers perceive their satisfaction with an impedance level and have attitudes about how important the impedance is.

These traveler characteristics influence the different ways different people respond to available travel choices. It follows that BART will affect the travel choices of people in different ways. Consequently, BART's impacts on accessibility, mobility, and traveler behavior need to be assessed with regard to the different affected groups, defined in terms of the situational and socioeconomic characteristics discussed above.

F--Characteristics of Potential Trips

The final component of the transportation system is the pattern of desired trips within the Bay Area. These, together with potential traveler characteristics, determine the "demand" for travel. The characteristics of this desired trip pattern is referred to as the characteristics of potential trips. These are determined by where and when people want to travel, i.e., origin-destination characteristics, trip purposes, and trip schedules.

Desired origin-destination patterns are defined in terms of the geographical distribution of land use activities which give rise to opportunities for different purposes of travel. The distribution of residences, characterized by the principal socioeconomic characteristics discussed earlier and the distribution of employment opportunities (categorized by income and occupation) together define the origin-destination pattern of work trips. Other important purposes of trip distributions are defined by the distribution of retail shopping facilities, educational facilities, medical facilities, and recreational facilities.

Trip patterns are also characterized by the desired time-of-day of travel and the urgency of the trip purpose. Both of these will influence the attitudes and, consequently, the behavior of travelers in considering trip decisions as will the day of the week and the season of the year. The size of the group traveling, whether or not baggage is being transported, whether the trip is a single-purpose trip or complex of several trip purposes, and whether or not the out-of-pocket expenses are chargeable as a business expense are characteristics of the trip which will also influence traveler behavior.

III. MAJOR QUESTIONS OF THE TRANSPORTATION SYSTEM AND TRAVEL BEHAVIOR PROJECT

The major questions to be evaluated during the course of the TSTB Project are set forth in this chapter. The proposed Project research program is oriented toward answering this set of specific questions concerning BART and its impacts on the Bay Area.

Recent technical literature[5] has criticized previous "impact studies," on the grounds of both conceptual structure and practical relevance. In particular, it has been argued that previous studies have all too often collected large quantities of data with little or no reference to a predefined analytical purpose or theoretical construct. In view of these concerns, considerable emphasis has been placed on developing a cogent, overall structure for the research investigations to be conducted in the TSTB Project. Overall, the investigations are structured in terms of a series of researchable issues and testable questions susceptible to at least partial evaluation. To the extent that viable theory exists in both economic and psychometric literatures, it is reflected in the structure.

Role of Questions in the TSTB Project

Four basic issues define the context of both the TSTB Project and the BART Impact Program as a whole. As noted in Chapter I, these are:

- What are the impacts of BART?
- Who is impacted by BART?
- Why do BART's impacts occur or not occur as expected?
- How can the information obtained from the BART experience be used to assist future transportation decisions?

These issues form the foundation for questions leading to a definition of what BART's impacts are, who is impacted, and why the impacts occur. Formulating and answering these questions is a central theme of the TSTB Project, and accordingly, this research plan. The answers to the what and who issues are derived from observation and measurement of impacts and their analysis in the context of appropriate statistical designs and controls.

The why issues regarding BART's impacts essentially determine why people behave as they do, in terms of both underlying causations and motivations. In particular, why do they or do they not ride BART. These issues also, to some extent, lead to more specific questions on traveler choice and behavior. For example, it is possible to structure a question to assess whether the comfort of the BART cars significantly affects BART ridership.

Through examination of these questions, the TSTB Project can achieve the important research objective of developing an improved understanding of the traveler decision-making rationale that underlies behavioral response to a new transportation facility such as BART.

The questions presented in this chapter provide the basis for responding to the what and who issues of BART's impacts and, to a more limited extent, the why issue. The findings and conclusions of these analyses will provide the basis for responding to the remaining why issues as well as the how issues. Therefore, this chapter does not contain specific questions pertaining to the how issues or to the development of models of traveler behavior. The TSTB Project approach to responding to these issues is presented in Chapter VI of this Research Plan.

Factors Used in Specifying Questions

Three factors were taken into account in specifying the sets of questions to be considered in the TSTB Project; questions were formulated for:

- Impacts which have been forecast or attributed to BART at successive stages in its planning, development, and operation--these include BART's impacts relative to people's expectations and what the impacts have been in an absolute sense.

- Policy, planning, design, and operating analysis requirements of decision-makers, planners, and citizens at the national, state, and local levels.

- A priori theoretical knowledge--although a fully developed impact theory is not currently available.

Expectations and Predictions Regarding BART's Impacts. It is important that questions on BART's impacts be framed in terms of those effects which were forecast, expected, or claimed before construction of the system. In part, this is necessary because similar forecasts and claims have been and are being used as the justification for investment in other transit systems. Accordingly, in listing the questions for assessment, many of the large number of papers and reports concerning BART's anticipated and early impacts have been reviewed. These include reports prepared at the early stages of BART planning;[2] reports of subsequent planning studies such as the Northern California Transit Demonstration Project;[6,7,8] Bay Area Rapid Transit District (BARTD) passenger forecasts and publicity, particularly those presented at the time of bond issue promotions; newspaper reports; papers and reports prepared by various researchers;[9,10,11,12] and a report on BART's anticipated and early impacts.[13]

Policy, Planning, and Design Analysis Requirements. Chapter I presented a discussion of the three principal categories of considerations concerning rail rapid transit which are of interest to decision-makers, planners, and citizens. These categories of considerations include: (1) traveler behavior and travel patterns responses to rail rapid transit, (2) transportation policy, planning, design, and operations considerations, and (3) social and equity considerations of rail rapid transit. A series of questions which have been raised concerning rail rapid transit and which are at least partially answerable in the context of a case study of BART were also presented. The questions in this chapter are designed to structure analyses that are responsive to these considerations and questions.

Theory. Desirably, all of the TSTB Project analyses should be based on a solid body of a priori theory regarding how and why impacts occur--a theory that has been developed and verified independently. Unfortunately, however, a well-established comprehensive theory describing the impacts which a system such as BART may have on transportation system performance and travel behavior patterns does not exist. It would be unrealistic to rely exclusively on what is a limited body of theory. However, to the extent that theory on transportation impacts[5,14,15] exists, it has been employed in developing the questions specified in this chapter.

Because of the lack of theory and based on the conceptual framework for the BART impacts processes (presented in Chapter II), the set of structured hypotheses on the impacts of BART are organized in terms of:

- BART-induced changes in transportation system attributes
- Imapcts of BART-induced attribute changes on transportation impedances
- Impacts of changed travel impedances on travel behavior

BART-Induced Changes in Transportation System Attributes

Costs of Providing Transportation Service. BART has some direct impact on the cost of providing transportation in the Bay Area; this varies as a function of the level of service BART provides. It is also impacting the costs of the entire transportation system insofar as (1) the attributes of other transportation services are modified in response to BART and (2) as traffic is diverted from other modes to BART. A list of the questions concerning BART's costs and the changes in the costs of the various other transportation modes in the Bay Area is presented in Exhibit 2.*

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*All exhibits (Exhibits 2 through 10) pertaining to questions are at the end of this chapter.

Energy Consumed in Providing Transportation Service. BART has impacts on the type and amount of energy consumed in two regards. The BART system consumes energy as a direct function of the level of service it provides; in fact, one can consider that consumption would occur, even if BART had no effect on the amount or modal distribution of travel. Secondly, BART has an impact on the total consumption of energy, in that it causes a reduction in the amount of travel by bus and, more importantly, by automobile. Offsetting this is the additional energy (if any) consumed as a result of traffic generated by BART. The TSTB Project will address the list of questions related to BART's energy consumption and the changes in the energy consumption of the other modes operating in the Bay Area as presented in Exhibit 3.

Changes in Transportation Impedances Resulting from BART-Induced Attribute Changes

Transportation Impedance Changes. Questions regarding BART's impacts on transportation impedances focus on the list of 30 user-perceived impedances provided in Appendix B because:

- A review of previous research studies suggests that these 30 impedances are of particular importance in the traveler decision-making process.
- It is anticipated that BART will affect these 30 impedances.

Exhibit 4 lists the principal questions to be addressed in the TSTB Project concerning the changes in transportation impedances resulting from the BART-induced attribute changes. In order to keep the list of questions a reasonable length, further specification on which groups in the BART impact area and which impedances have been affected is not provided. More specific questions at this next level of detail will be determined at the time that the detailed analyses are designed. It should be noted that the initial analyses will probably result in some refinement of the initial questions and the specification of additional questions.

Many of its proponents see the advantages of BART, not so much in terms of the travel cost and time savings it provides to travelers, but in the "quality-of-service" improvements it offers to both bus travelers and automobile drivers. For this reason, hypothesized improvements in these qualitative impedances and other transportation impedances will be investigated during the course of the TSTB Project.

A change in one or more of the list of travel impedances for either of these traveler groups can be considered a change in accessibility to desired trip destinations, where accessibility is broadly defined in terms of travel impedances. (If a more conventional definition of accessibility is adopted, then BART impacts the accessibility of travelers to desired trip locations only insofar as the total travel time impedance changes.) The mobility of

disadvantaged groups may be affected by changes in the impedances in particular ways. BART's differential impacts on the mobility of disadvantaged groups of the Bay Area's population are also discussed in some detail below.

Traveler Attitudes Impacts. As BART service is introduced and improved, travelers and the general public will develop an increased awareness of the system and experience its operation. As this happens, attitudes about BART and, hence, public transportation in general will be established or changed. The attitudes of those who have never ridden on BART cannot be expected to change in a significant way, except insofar as they are influenced by second-hand reports. However, those who have traveled by BART can be expected to have significantly changed attitudes, in that they will perceive changes in the 30 impedances identified in Appendix B. It can be hypothesized that perceptions will influence attitudes in broad terms and also attitudes on specific BART system impedances. A set of questions pertaining to the most important anticipated attitude changes associated with BART is presented in Exhibit 5.

Impacts of Changed Travel Impedances on Traveler Behavior

Traveler Choice Behavior as a Function of Changed Impedances. The introduction of successive BART service improvements and full-system operation will cause changes in individual traveler behavior in each of the seven dimensions of traveler behavior discussed in Chapter II. These travel behavior changes arise through the travelers' decision-making process which responds to changes caused by BART in the impedances of the transportation system. The questions presented in Exhibit 6 are designed to investigate the anticipated individual traveler behavior impacts of the initiation of BART service.

Aggregate Travel Patterns Impacts. The aggregation of individual travel behavior changes over the entire transportation system gives rise to changes in the distribution of vehicle traffic on the system's highways and the ridership on the routes and links of the transit system. A set of questions regarding the impacts of BART on regional travel patterns is presented in Exhibit 7.

Impacts of Changes in Travel Patterns on Highway Congestion. The redistribution of travel patterns among the modes of the transportation system as a result of BART initiates a number of changes in highway traffic congestion. Questions on these changes are described in Exhibit 8.

Secondary Traveler Behavior Changes Resulting from the Revised Travel Patterns. The feedback between the aggregate travel patterns changes resulting from BART and the impedances (and to some extent the attributes)

of the transportation system was shown in Chapter II, Exhibit 1. These secondary impacts on the impedances of the transportation system resulting from the changed traffic patterns will, in turn, cause additional modifications of individual traveler behavior; questions regarding these secondary impacts are presented in Exhibit 9.

Impacts of BART on Accessibility and Travel Behavior of Disadvantaged Groups

BART's impacts on the accessibility and traveler behavior of the disadvantaged may differ significantly from corresponding impacts on the general population. To properly assess the social and equity considerations with respect to BART, the TSTB Project will conduct a subproject to assess BART's differential impacts on the accessibility and travel behavior of disadvantaged groups. This effort--which will cut across all of the prinicpal TSTB areas of investigation--will use special survey research techniques as described in Chapter VII. The principal questions to be investigated in this effort to assess BART's impacts on disadvantaged groups are presented in Exhibit 10.

These questions are specifically oriented to an analysis of disadvantaged groups in relation to BART. The analysis is not intended to provide a comprehensive assessment of the total unmet travel needs of disadvantaged groups. Rather, it is explicitly intended to assess these needs insofar as they relate to BART and to determine how the service that BART was designed to provide to disadvantaged groups can be further improved.

A much larger proportion of whites have middle level incomes than minorities; and in terms of their numbers, a much higher proportion of minorities have lower level incomes. Because members of racial and ethnic minorities are far more likely to be economically disadvantaged than whites, they are more likely to make a careful budgetary assessment of the relative costs of travel by BART, bus, or car.[16] For this reason, questions pertaining to BART's impacts upon ethnic minorities and low income residents with limited access to an automobile are combined.

Exhibit 2

BART-INDUCED CHANGES IN
TRANSPORTATION SYSTEM ATTRIBUTES--COST

1. What is presently estimated as the final construction cost of BART?

2. What are the construction costs for specific elements of the system?

3. How do the actual and anticipated construction costs differ from the estimate provided in the 1962 Composite Report and why?

4. How do the construction costs of BART compare to the construction costs of other rail rapid transit systems?

5. What are the current operating costs for BART?

   - Total?

   - On a unit basis (per passenger mile)?

6. What are the costs for different elements of system operation (e.g., labor, energy and materials within operations, maintenance, and administration)?

7. Have BART's unit operating costs decreased with the increased scale of system operation?

8. How do BART's unit operating costs compare to those of other rail rapid transit systems?

9. How do BART's unit total (operating plus annualized capital) costs compare to those of other rail rapid transit systems (e.g., has the BART investment in automation resulted in net economic benefits)?

10. How do BART's unit operating and unit total costs compare to those of other modes?

11. What are the net cost savings to the Bay Area resulting from the construction of BART?

12. Will the construction of BART postpone or reduce the need and, therefore, cost of additional freeways, parking facilities, other transportation facilities (such as the proposed Southern Crossing of San Francisco Bay), and additional buses?

13. Will the diversion of travel from automobile to BART reduce automobile ownership and the associated costs in the long run?

14. What is the relationship between BART's operating costs and its operating revenues?

Exhibit 3

BART-INDUCED CHANGES IN
TRANSPORTATION SYSTEM ATTRIBUTES--ENERGY

1. What is BART's energy consumption?

   - Construction
   - Operating
     - Maintenance
     - Station
     - Traction

2. Has BART's efficiency of energy consumption improved with the increasing scale of system operations, and if so, why has the efficiency changed?

3. How does BART's energy consumption compare to that of other rail rapid transit systems?

4. How does BART's energy consumption compare to that of other modes?

5. What is the diurnal pattern of BART's energy demand, and how does this compare to the diurnal pattern of regional electrical energy demand?

6. What are the net energy savings to the San Francisco Bay Area resulting from the construction of the BART system?

7. Will BART significantly decrease the energy consumed in automobile transportation in the Bay Area, as reflected by vehicle-miles of travel (VMT)?

8. Will BART significantly decrease the energy consumed by line-haul and feeder bus transportation services in the Bay Area?

9. Will BART allow a more efficient use of available energy resources by utilizing electrical energy, which can be generated from a number of alternative fuels?

Exhibit 4

BART-RELATED CHANGES IN
TRANSPORTATION SYSTEM IMPEDANCES

The following questions apply to each of the 30 impedances that BART is expected to change. These are listed in Appendix B.

As discussed in Chapter VII, the levels of the impedances can be estimated using both physical and perceptual measurements. Both types of measurements are contemplated for those questions comparing the levels of impedances.

1. For all potential trips in the BART impact area and for particular geographically and demographically defined market segments, has BART decreased or increased the impedance level when compared to the transit services available immediately prior to BART service?

2. For all potential trips in the BART impact area and for particular geographically and demographically defined market segments, does BART provide a lower or higher impedance level when compared to the currently available transit service?

3. For all potential trips in the BART impact area and for particular geographically and demographically defined market segments, does BART provide a lower or higher impedance level when compared to the currently available automobile service?

4. For all potential trips in the BART impact area and for particular geographically and demographically defined market segments, has the introduction of BART service resulted in a change in the impedance level of the competing and complementary transit and highway services?

5. How have the impedance levels changed for those BART travelers who diverted from other transit services?

6. How have the impedance levels changed for those BART travelers who diverted from automobile?

7. What particular geographic areas of the region and travel market segments (as defined in Exhibit 11) have had their travel impedances:

   - Improved as a result of the introduction of BART?
   - Unaffected by the introduction of BART?
   - Adversely affected by the introduction of BART?

Exhibit 4 (Cont.)

BART-RELATED CHANGES IN
TRANSPORTATION SYSTEM IMPEDANCES

8. How have the impedances associated with BART changed over time as BART moves from a transitional period of system operations to full-system operation?

9. How can BART service be improved, particularly when (1) BART has a higher impedance than competing transit and automobile services, and (2) the given impedance is of major importance to the travel decisions of potential BART travelers?

10. For all potential trips in the BART impact area and for particular geographically and demographically defined market segments, are the impedances associated with the BART alternative lower or higher than those associated with various hypothesized no-BART alternatives?

Exhibit 5

BART-RELATED CHANGES IN
TRAVELER ATTITUDES

1. What is the relative importance of each of the 30 impedances identified in Appendix B in influencing travel behavior for:

   - Those travelers who divert to BART?
   - Those potential BART travelers who do not divert to BART?
   - The general population of travelers?

2. What is the relationship between the perceptual and physical measurements of an impedance for the general travel population and for geographically and demographically defined travel market segments?

3. As BART service is extended and improved, will previous automobile travelers' attitudes on BART, as reflected by their perceived satisfaction with the relative levels of modal impedances change? Will such changes result in an improved willingness of automobile travelers to switch to BART?

4. As BART service is extended and improved, will the previous bus travelers' attitudes on BART change in a similar way with regard to specific impedances? Will such changes result in an improved willingness of bus travelers to use BART?

5. As bus services paralleling BART are reduced, will some previous bus travelers experience a reduction in the overall level of service provided by the transit system and have correspondingly worsened attitudes on the system?

6. Overall, will the attitudes of the public to the total transit system of the Bay Area and particularly to the BART system be improved, and correspondingly, will the willingness of people to use transit and to provide community support for transit be increased?

Exhibit 6

BART IMPACTS ON INDIVIDUAL TRAVELER BEHAVIOR
DUE TO CHANGED TRAVEL IMPEDANCES

1. Trip Frequency

- Will travel induced by BART increase the total number of trips made?

- Will trips be made on BART that would not have been made, or would have been made less frequently, if BART were not available?

- Will this be especially true for travel across the San Francisco Bay for shopping purposes?

- Will there be resulting increases in travel time, cost, and effort to travelers? Will these be equal to, or exceeded by, the value to the travelers of being able to make the trips? Will these induced trips tend to be made by those segments of the community who would otherwise be relatively immobile, especially those without cars?

2. Time of Travel

- Will BART alter the scheduling of trips?

- Will BART riders who previously used automobile or bus, and modified their travel schedule to avoid traffic congestion, now be able to schedule their trips to adhere more closely to their "ideal" travel schedule?

- Will the shortage of parking space at some BART stations cause some travelers to travel earlier than before in order to find a parking space?

3. Destination Choice

- Will there be changes in the origin-destination pattern of trips?

- Will BART encourage travelers to make longer trips than they would make otherwise? Will this be especially true for travel across the Bay?

- Will the change in trip length distribution in the short run be mainly for shopping and other nonwork purposes?

Exhibit 6 (Cont.)

BART IMPACTS ON INDIVIDUAL TRAVELER BEHAVIOR
DUE TO CHANGED TRAVEL IMPEDANCES

- Will work trips also become longer as work and residence locations are affected by the increased accessibility provided by BART in the longer term (especially as work trips increase between Contra Costa and Alameda Counties and San Francisco)?

- Will increases in trip lengths, times, and costs result? Will these be offset by the benefits enjoyed by the travelers making the trips at their origins and/or destinations?

4. Mode and Route Choice

- Will there be a change of travel mode from bus transit to BART for the same trips as previously made, and a corresponding reduction in the level of bus service provided? Will this diversion affect usage of the modes which access BART, causing an increase in both the use of automobile and bus feeder modes to the BART station?

- Will there be a change in travel mode from automobile to BART for some travelers? Will this take place in all corridors served by BART, and be especially marked for work travel across the Bay to San Francisco?

- Will the alternative of taking BART be particularly attractive to those who previously shared cars or car pooled. Alternatively, will those who car pool be more sensitive to the costs of BART and, consequently, be less inclined to divert to BART?

- Will travelers be more likely to use AC Transit or MUNI as an egress mode from BART (when a free transfer is provided) than as an access mode to BART (when the traveler must pay both AC Transit or MUNI and BART fares)?

5. Behavior While Traveling

- Will travelers who diverted from automobile to BART be able to increase productive use of travel time because automobile drivers no longer have time occupied and because automobile passengers have an improved ride quality? Similarly, will travelers who diverted from bus to BART be able to use their time more productively because BART provides an improved ride quality?

- Will vandalism on BART be relatively less than vandalism on corresponding bus transit services because potential vandals will have relatively more respect for BART's high quality appearance and because of BART's police services?

Exhibit 6 (Cont.)

BART IMPACTS ON INDIVIDUAL TRAVELER BEHAVIOR
DUE TO CHANGED TRAVEL IMPEDANCES

6. Automobile Ownership

- Will the rate of automobile ownership in the longer run be reduced in households where the principal work trip traveler diverts to BART and does not require an automobile to access BART?

Exhibit 7

IMPACTS OF CHANGED INDIVIDUAL TRAVEL BEHAVIOR UPON AGGREGATE TRAVEL PATTERNS AS A RESULT OF BART

1. Will there be reductions in total automobile traffic on major arterials and freeways paralleling BART lines? Will there be significant reductions in the East Bay on:

   - Interstate 80 leading to the Bay Bridge from the north?
   - Route 24 leading to the Bay Bridge from central Contra Costa County through the Caldecott Tunnel?
   - Route 17 leading to downtown Oakland and the Bay Bridge from southern Alameda County?
   - Interstate 580 from southern Alameda County?

2. Will there be some reduction in the West Bay in total automobile traffic on major arterials and freeways paralleling the BART lines? In San Francisco in particular, will there be some total traffic effects on Interstate 280 from San Mateo County and Daly City to San Francisco?

3. Will there be reductions in the total automobile traffic on two transbay bridges? Will the largest reduction be experienced on the San Francisco-Oakland Bay Bridge with a much smaller but still measurable reduction on the San Mateo-Hayward Bridge?

4. Will there be a change in the distribution of traffic on these highways by vehicle type and by time of day? In particular, will the changes in traffic volume by time of day be more significant than the reductions in the total traffic volume?

5. Will traffic on local streets in the immediate vicinity of the BART stations increase, particularly at suburban BART stations with large parking facilities and relatively little feeder bus service?

6. Will the demand for parking facilities in the CBDs of San Francisco and Oakland decrease because automobile travelers will divert to BART?

   - Will the decline in the space-hours of parking space usage be even greater than the reduction in the total number of vehicles parked? This might be expected because diversion to BART will be mainly by work travelers who park for longer times than other travelers.

Exhibit 7 (Cont.)

IMPACTS OF CHANGED INDIVIDUAL TRAVEL BEHAVIOR UPON AGGREGATE TRAVEL PATTERNS AS A RESULT OF BART

7. Will ridership on BART system lines increase in response to incremental service improvements?

8. Will most ridership on Greyhound buses from the East Bay be diverted to BART, resulting in major reductions in service?

9. Will AC Transit ridership be significantly affected by introduction of BART service?

    - Will ridership on transbay AC Transit buses decrease as BART transbay service develops capacity to handle increased ridership, resulting in reductions in AC Transit service?

    - Will ridership on other AC Transit routes paralleling BART lines decrease, resulting in reductions in AC Transit service?

    - Will ridership on AC Transit feeder services to BART stations increase, resulting in increases in AC Transit service?

10. Will San Francisco Municipal Railway (MUNI) ridership be affected by the introduction of BART service?

    - Will bus and streetcar services paralleling the Daly City to Montgomery Street BART line have reduced ridership?

    - Will ridership be reduced on MUNI lines connecting with the East Bay bus terminal?

    - Will ridership of feeder services to BART stations increase, resulting in increases in service?

Exhibit 8

IMPACTS OF CHANGED TRAVEL PATTERNS
ON HIGHWAY CONGESTION DUE TO BART

1. Will BART have the effect of reducing traffic congestion (as manifested in decreased traffic time)? Will this occur principally on the Bay Bridge, the major freeways leading to it, and on Route 24 through the Caldecott Tunnel?

2. Will the time periods during which traffic congestion occurs initially be reduced as those automobile drivers who continue to drive adjust their trip scheduling to the reductions in traffic caused by the diversion of automobile drivers to BART?

3. Will there be increases in the levels of congestion on local streets leading to BART stations at the peak periods, with resulting disbenefits to the residents of the area? Will there also be congestion in the vicinity of some stations caused by the overflows from the BART parking lots?

4. Will highway congestion reductions cause a reduction in highway traffic accidents and corresponding reductions in insurance costs? Will there also be savings in automobile fuel consumption and operating costs? For those who continue to drive, will there be reductions in travel time and effort?

Exhibit 9

BART-INDUCED IMPACTS ON INDIVIDUAL TRAVELER BEHAVIOR
RESULTING FROM SECONDARY TRAVEL PATTERNS IMPACTS ON IMPEDANCES

1. Will additional automobile travel be undertaken as a result of the reduced traffic congestion? Will this involve a change in destination for automobile trips previously made, automobile trips not previously made, or transit trips previously made?

2. Will there be a tendency for travelers to shift their time of travel as a result of reduced traffic congestion and other changes in travel attributes induced by BART service?

   - Will commuters who drive early or late, to and from work, now drive at a more convenient time?

   - Will this effect occur on the Bay Bridge and have the effect of "sharpening" the peak morning and evening traffic volume pattern?

3. Will automobile drivers divert from the San Mateo-Hayward Bridge to the Bay Bridge as drivers using the Bay Bridge divert to BART and traffic congestion on the Bridge is reduced? Will additional trans-bay automobile trips be made as a result?

4. Will some bus travelers divert to BART or automobile, or suppress their trips, because of the reductions and, in some cases, suspensions of parallel bus services resulting from the diversion of other bus travelers to BART?

5. Will automobile drivers divert from parallel arterial streets to the freeways as traffic congestion on freeways is reduced?

6. Will the diversion of automobile travel to BART result in other members of the household making trips with the now-available car which would not otherwise have been made or would have been made by bus?

Exhibit 10

IMPACTS OF BART ON ACCESSIBILITY AND TRAVEL BEHAVIOR OF DISADVANTAGED GROUPS

As discussed in Chapter IV, the TSTB Project will consider BART's impacts on the following disadvantaged groups of Bay Area residents: (1) ethnic minorities, (2) physically handicapped, (3) elderly, (4) youth, and (5) low income residents with low automobile availability. A set of questions on BART's impacts on disadvantaged groups in general is presented first, followed by specific questions pertaining to each of the five groups.

All Disadvantaged Groups

1. Does BART increase the transit accessibility of disadvantaged groups to (1) higher paying jobs, (2) health care facilities, (3) educational facilities, (4) public and private service organizations, (5) recreational facilities, (6) lower priced and better shopping facilities, and (7) social opportunities?

2. Are disadvantaged groups taking advantage of the improved transit accessibility provided by BART? What are the motivations underlying this response to BART?

3. For the segment that uses BART regularly, and the segment that does not use BART, are the perceptions, attitudes, and travel behavior of disadvantaged groups with respect to BART different from those of the population in general? What are the motivations underlying the differences in response to BART?

4. Has BART improved the "quality of life" of disadvantaged groups by providing improved mobility to a greater variety of activities?

5. Has BART improved the economic condition of disadvantaged groups by reducing the need for investment in an automobile and increasing accessibility to higher paying jobs?

6. What are the major factors which constrain the use of BART by the disadvantaged?

7. What actions could be undertaken to increase the use of BART by the disadvantaged?

Ethnic Minorities and Low-Income Residents

1. Has BART increased accessibility to jobs for ethnic minorities located at the lower end of the occupational and income ladders? Do these jobs provide lower or higher wage levels than those previously available?

Exhibit 10 (Cont.)

IMPACTS OF BART ON ACCESSIBILITY AND
TRAVEL BEHAVIOR OF DISADVANTAGED GROUPS

2. All other factors, particularly income, remaining constant, is BART used for home-to-work-to-home commuting more by whites than by ethnic minorities relative to their participation in the labor force?

3. Will BART increase the access of ethnic minorities to government service agencies such as those concerned with unemployment compensation and welfare?

4. Among those who previously used another mode of transit, will a greater percentage of the total number of whites divert from this other mode of transit to BART than will be the case among ethnic minorities, all other factors remaining constant?

5. If a greater proportion of white bus riders divert from bus to BART than ethnic minority bus riders, will this have a multiplier effect on the travel behavior of whites further encouraging them to divert from the bus to either BART or automobile?

6. As travelers divert from bus to BART, will bus service in ethnic minority and low-income communities be reduced? If bus service is reduced, will ethnic minorities and low-income residents who continue to use bus have an increased exposure to violent assault because of the increased waiting times for and walking distances to bus service?

7. Will a higher proportion of the ethnic minority than white BART users take trips that would not have been taken if BART were not available?

8. All other factors, particularly income, remaining constant, will more ethnic minority group members than whites be likely to respond positively to changing their mode of transportation from car or bus to BART, if BART fares were lowered to a level equivalent to the out-of-pocket cost of the other modes?

9. Will BART improve the access of minority group members to their respective communities in the East and West Bay, and thus to their kinship networks and cultures?

10. Will ethnic minorities, especially those at the lower end of the occupational and income ladder, be less likely than whites with equivalent incomes to identify with the social and physical environment of the BART trains and stations, and will this act as an impedance to their use of BART?

Exhibit 10 (Cont.)

IMPACTS OF BART ON ACCESSIBILITY AND
TRAVEL BEHAVIOR OF DISADVANTAGED GROUPS

11. If the introduction of BART service does result in reduced automobile ownership among ethnic minorities, will these ethnic minorities experience a reduced self-image because of the reduced automobile ownership?

12. Will ethnic minorities modify their attitudes toward public transit at a different rate than the general population as (1) incremental improvements to BART service are accomplished and (2) local bus service to ethnic minority communities is reduced?

Physically Handicapped

1. Will BART have a significant impact on the travel behavior of the handicapped? Will it increase their accessibility to education, recreation, shopping, and work opportunities?

2. What are the major impediments to the greater use of BART by the physically handicapped? Does the fear of social embarrassment and public attitudes constitute an important barrier to the greater use of BART by the physically handicapped?

3. What actions could BART take to increase its service to the physically handicapped? Will BART better serve the travel requirements of the physically handicapped by providing a feeder system that would accommodate the physically handicapped as successfully as BART itself?

Elderly and Youth

1. Does BART significantly increase the accessibility of elderly people and those too young to drive?

2. All other factors remaining constant, are elderly people and those too young to drive utilizing the improved transit accessibility provided by BART?

3. What are the major impediments to the greater use of BART by elderly people and those too young to drive (e.g., financial constraints, physical limitations, fear of assault or social embarrassment in a public situation, nervousness because of the speed, scale, and crowding of the system)?

4. What actions could BART take to increase its service to elderly people and those too young to drive? Will elderly people and youth be able to make better use of BART when the system provides evening and weekend service?

IV. ESTABLISHING RESEARCH PRIORITIES

Resource limitations preclude extensive study of all of the impacts of BART on all potentially impacted groups throughout the entire Bay Area. Thus, it is necessary to establish some priorities for the impedances, travel market segments, geographic segments of the Bay Area, and variables to be studied. These research priorities are described in this chapter.

Assessment of Impedance Changes

BART is expected to induce changes in the 30 impedances listed in Appendix B. These impedances are believed to influence traveler choices. Not all of them can be studied at the same level of detail during the course of the TSTB Project, and it is necessary to establish some priorities for investigation of the impedances. Three general levels of investigation will be employed:

- Level 1--Impedances which can be incorporated into existing models developed to explain travel behavior.
- Level 2--Impedances which will be studied intensively and if possible, incorporated in models of traveler behavior.
- Level 3--Impedances which are important but can only be subjected to exploratory study because of limitations in both available data and traveler behavior theory.

Impedances Numbers 1 through 4 in Appendix B will be considered at the first level of investigation during the course of the TSTB Project; these are the travel time and travel cost variables currently used in most urban travel models. On the secondary level of investigation, an effort will be made to incorporate the following impedances into travel models developed during the course of the TSTB Project: reliability of on-time arrival (Numbers 7 and 8), the quality of the transit ride (Numbers 9, 22, 23, and 26), seat availability (Number 15), and the availability of parking (Number 17). Finally, the remaining impedances will be studied at the third or exploratory level of investigation.

Selection of Study Areas

The TSTB Project will, by definition, focus on the "BART impact area." The BART impact area is defined as that geographic region from which travelers are drawn. The May 1974 on-board surveys conducted by BART on the East and West Bay lines and the October 1974 on-board transbay survey conducted by the TSTB Project will be utilized to determine a first approximation of the BART impact area. This area will probably include, at a minimum, the three counties constituting the BART district, as well as

the northern section of San Mateo County. Subareas for intensive study within the overall BART impact area will be selected based on:

- The inherent importance of the areas
- A mapping of transit accessibility before and after the introduction of BART

Selection Based on Inherent Importance. Several considerations enter into an assessment of the inherent importance of a particular subarea:

- Whether the geographic unit constitutes a controlled environment for assessing BART's impacts.
- Whether population subgroups of particular interest to the TSTB Project reside, work, or perform other activities within the subarea.
- Whether appropriate "before" data are available for the given subarea when such data are required for the particular research design of the TSTB Project.

There are two controlled environments within the Bay Area which are of particular interest for assessing BART's impact on travel behavior and patterns--the Bay Bridge link between Oakland and San Francisco and the Caldecott Tunnel link between central Contra Costa County and Oakland. Along each of these links, there are essentially no alternative travel routes available for automobile, bus, or BART travelers. Since both links are corridors where BART captures a substantial portion of the travel market, on-route multimodal surveys on these two links provide an approach for obtaining a relatively large sample travel survey at a relatively low cost as compared to home interview or telephone survey techniques.

One of the objectives of the TSTB Project is to assess BART's impacts with respect to special subgroups of the Bay Area's population, particularly the disadvantaged (see Exhibits 10 and 11). Since some disadvantaged groups tend to reside within a relatively limited subregional area, the TSTB Project will select these subareas for more intensive study to assess BART's impacts on these groups. In particular, Surveys 5 and 7 which are described in Chapter VII are specifically designed to obtain greater samples of respondents representative of disadvantaged groups than the relative proportion of these disadvantaged groups within the general population.

Many of the research designs to be used in the TSTB Project involve some form of before and after comparisons of a particular variable. In order to use these research designs, it is necessary to acquire the "after" data in the same location where the "before" data were obtained. This consideration largely defines the geographic areas where the "after" BART impact

Exhibit 11

MARKET SEGMENTS TO BE CONSIDERED IN THE TSTB PROJECT

- Journey to work of middle- and high-income workers living in communities on both sides of the Bay with destinations in CBDs of Oakland or San Francisco.
- Journey to work for residents of the center cities of Oakland and San Francisco to non-CBD employment locations; this is frequently referred to as "reverse commuting."
- Journey of students to higher educational facilities.
- Shoppers traveling to the CBDs of San Francisco and Oakland for shopping.
- Persons traveling to the center cities of San Francisco and Oakland for recreational and cultural purposes.
- Travel by the physically handicapped.
- Travel by the elderly.
- Travel by youth.
- Travel by low-income groups.
- Travel by ethnic minorities.
- Travel by groups with low automobile availability.

travel surveys and the "after" BART telephone surveys (Surveys 1 and 5, respectively, in Chapter VII) will be conducted during the TSTB Project.

Selection Based on Pre- and Post-Transit Accessibility Mappings. When the selection of the study site is not constrained by the considerations noted above, the selection will be partially based on pre- and post-transit accessibility mappings of the Bay Area. During Phase I of the TSTB Project, transit networks are being developed to represent the transit system that existed in the Bay Area in 1971 immediately prior to the initiation of BART and the transit system that will exist in 1976 when BART is in full operation. The transit accessibility of zones within the BART impact area will be assessed for the 1971 and 1976 conditions using these transit networks. By comparing the 1971 and 1976 transit accessibility indices for specific zones or areas of the region, it will be possible to assess the impact of BART on the transit accessibility of the specific areas. Those zones where the greatest changes in transit accessibility occurred will be selected as the sites for specific detailed investigation; those zones where the smallest changes in transit accessibility occurred will be selected as the "control" sites as discussed in Chapter V.

Market Segments

The characteristics of potential travelers and potential trips give rise to the concept of segmenting the travel market into different types of trips made by different traveler groups.*

Prior to the actual conduct of the analysis, it may not be possible to anticipate all of the market segments that may be analyzed by the TSTB Project. A preliminary list of the market segments to be examined in the course of the TSTB Project is presented in Exhibit 11. These market segments were selected based on the following criteria:

- Selected market segments appear to constitute a relatively large proportion of BART usage, based on available data.
- Selected market segments are those that, prior to BART's construction, were expected to be significantly impacted by BART.
- Selected market segments are of current interest from a policy point of view (e.g., the physically handicapped, aged, youth, reverse commuters, and all other travel by low-income and ethnic minority residents).

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*The BART Market Segments Project currently being undertaken by BARTD will categorize the traveler population in this way in order to define market groups for marketing efforts. The results of the BART Market Segments Project will be evaluated for use in the TSTB Project.

Special groups whose travel needs will be given particular attention in the TSTB research include:

- Low-income groups.
- Ethnic minority groups.
- Elderly people.
- Those who are physically handicapped (e.g., required to use wheelchairs, crutches, or canes, or who are blind or deaf).
- Youth.
- Individuals who are unable to drive or have limited access to an automobile.

The analysis will consider as a group those who have a low automobile availability (where automobile availability is defined in terms of the possession of a valid driver's license and access to a usable automobile). This group has been referred to as "transit captives," inasmuch as those with a low automobile availability do not have a viable alternative to transit. Many individuals who are members of the special groups identified above (i.e., low-income residents, ethnic minorities, the elderly, youth, and those who are physically disabled) are also members of the group with low automobile availability.

Inasmuch as women constitute about 50% of the population of the BART impact area, they have not been identified as a special group or market segment in Exhibit 11. The analysis, however, will assess the impacts of BART on women and the special travel requirements of women.

Independent Variables to Describe Potential Traveler and Trip Characteristics

As appropriate in the various surveys of the TSTB Project, the following variables will be used to describe traveler characteristics: sex, age, educational level, ethnic identification, income, years of residence within the metropolitan area, ability to communicate in English, physical capabilities, and possession of a valid driver's license. In addition, the following variables will be used to describe the traveler's household: household income, number of automobiles owned, number of workers in the household, and number of individuals in the household possessing a valid driver's license. Similarly, the characteristics of potential trips will be described, as appropriate, in terms of the following variables: origin-destination characteristics, trip purpose, time-of-day of travel, size of the group traveling, whether or not baggage is being transported, whether or not the trip is a single-purpose trip or a complex of several trip purposes, whether or not out-of-pocket expenses are chargeable as a business expense, whether or not an automobile is needed for business purposes.

In its data policy for the BART Impact Program, the Metropolitan Transportation Commission (MTC) has established strata and conventions for the description and coding of many of these variables.[17] Where conventions for a particular variable have been established by MTC, they will be utilized in the TSTB Project. The MTC data policy provides conventions for the greatest possible level of detail for a particular variable (for example, 18 income categories are allowed). On occasion, therefore, the TSTB Project will need to aggregate the MTC data categories into a smaller number of classifications which are amenable to a field survey.

V. RESEARCH METHODS: EXPERIMENTAL DESIGN

The analytical approach of the TSTB Project is described in two chapters. The experimental designs to be used in the TSTB Project are described in Chapter V, and the approaches for evaluating and interpreting the results--particularly transferability to other metropolitan areas--are presented in Chapter VI. Chapter V describes the broad strategy to be used in the TSTB Project to investigate questions on the transportation system and travel behavior impacts of BART described in Chapter III. Since the questions focus on the what and who of BART's impacts, this chapter details the analytical approaches to developing answers to the what and who questions. The research methods leading to the explanation and interpretation of the impacts (that is, responses to the questions of "why do the impacts occur" and "how can the lessons from the BART experience be transferred") are described in Chapter VI.

Initially this chapter describes the types of analyses and research designs to be used in assessing each of the hypothesized areas of BART impacts described in Chapter III. The remaining two sections describe the research approaches which will be used to address one of the major methodological problems of the research--the problem of control. That is, among the diverse changes that occurred concurrent with the introduction of BART service, how many can actually be attributed to BART?

Confounding Factors Affecting Analysis of BART's Impacts on Travel Patterns

The TSTB Project must address the difficult technical problem of assessing the extent to which the changes in the transportation system and travel behavior which occurred concurrent with the introduction of BART service between 1972 and 1976 can be attributed to BART. During this same time period, there were many other factors affecting the transportation system and travel behavior in the Bay Area, and it is necessary to utilize research methods that distinguish between the effects of these other factors and the effects of BART.

The principal factors confounding the assessment of BART's impacts include (1) the changes in the economic climate over time; (2) the changes in the transportation system which are unrelated to BART; (3) the changes in the distribution of urban activity over time; and (4) the inherent seasonal, monthly, weekly, daily, and hourly variations in travel patterns. The nature and implications of each of these types of confounding variables are briefly described in this section.

Economic Climate. Major changes in the national economic climate have occurred concurrent with the introduction of BART; these economic changes have been manifest in the Bay Area. The principal economic factors that could affect travel behavior in response to BART are: (1) the

relatively large increase in unemployment levels in the last quarter of 1974 and continuing in 1975, and (2) the major inflation in the cost of living between 1972 and 1975. There is some evidence from transit patronage data for other metropolitan areas that increased unemployment reduces transit patronage for home-to-work travel. Employee wages have generally increased as a result of the inflation in the cost of living, including the compensation levels of BART employees. Thus, BART's expenses have increased dramatically during this period. On the other hand, there has been no adjustment in the BART fare schedule during the same period; consequently, in constant dollars, BART fares have actually decreased during the period of BART service introduction.

Other Transportation System Changes. Significant changes have occurred in the transportation system--particularly the automobile system--both nationally and in the Bay Area during the period of BART service introduction. The two most important changes to the automobile system have been the major increase in the price of gasoline in 1974 (and the unavailability of gasoline during certain portions of that year) and the substantial increase in the price of automobiles when the 1975 models were introduced. In both cases, the price increases occurred at a significantly greater rate than the overall increases in wages and the cost of living; thus, the relative cost of an automobile in real-dollar terms increased during this period. Other modifications in the Bay Area transportation system which have occurred concurrent with the introduction of BART service include the provision of reserved lanes for car pools and buses on the Bay Bridge and the two-month strike of AC Transit employees in the summer of 1974. In the immediate future, other changes may take place that could also affect BART patronage. Examples of these are the possible imposition of parking constraints in the CBDs of San Francisco and Oakland and the continuing trend toward smaller, more economical automobiles. Some of these changes may have a relatively direct impact on BART patronage, while others may have a more obscure effect in that they may affect basic attitudes toward travel, rather than having a direct impact on BART patronage.

Development Changes. Between 1971 and 1975, a large number of development decisions were made in the Bay Area that may or may not have been influenced by BART. Travel patterns in the region have been modified as a result of these changes in various subareas of the region. One example of this is the relatively rapid development of central Contra Costa County in the early 1970s--particularly the area served by the Walnut Creek BART Station.

Variations in Travel Patterns. The final complicating factor--variations in travel patterns--is not so much a change which occurred concurrent with BART, but rather a factor which must be carefully considered in interpreting "before" and "after" travel patterns. Analyses of travel patterns indicate that there are major variations in traffic volumes in different seasons of

the year, months of the year, days of the week, and hours of the day. For example, July is generally a high traffic month, while January is a low traffic month. Similarly, all other factors being equal, there is generally a greater volume of automobile traffic on Fridays than on other weekdays.

Quasi-Experimental Designs for Assessing BART's Impacts on the Transportation System and Travel Behavior

Several writers have addressed the topic of the use of quasi-experimental design in the context of transportation research,[5] and no attempt will be made in this research plan to cover the issue in-depth. However, a number of important and relevant points should be made. First, experience has shown that simple "before" and "after" designs with little or no control are of limited use in identifying specific impacts. Comparison of "test area" results with those from equivalent "control areas," supposedly outside the influence of the phenomenon under study (in this case BART), may also give dangerously misleading results. Strictly, in order to obtain meaningful results, it is necessary that any form of inferential statistical analysis be set in the format of a formalized experimental design.

In most instances of transportation impact assessment, a design in the pure Fisherian tradition is infeasible because of the complexities of the environment within which impacts arise. Aside from the parallel problems of measurement, timing, and sample selection, this complexity makes anything other than a very simple experiment virtually impossible to design. The analyst has little or no control over the multitude of external influences which Fisherian designs are explicitly structured to exclude.

Reliance must be placed, therefore, on an alternative approach built around the concept of quasi-experimental design as developed by Campbell and Stanley[18] and others. These designs are so structured as to "randomize out" potentially confounding effects surrounding a given uncontrolled event through the process of sample selection. They are essentially analysis plans "in the tradition of experimental design for the study of nonexperimental events."[5]

The five quasi-experimental designs which will be used in the TSTB Project to separate the BART-induced effects from other effects caused by the confounding variables are summarized in Exhibit 12. These five quasi-experimental designs basically represent different combinations of the following four general types of control mechanisms:

1. Comparison of geographically defined "test" and "control" groups; these groups will probably be defined in terms of proximity to the BART system, using among other analyses, the pre- and post-BART service transit accessibility analyses discussed in Chapter IV.

Exhibit 12

QUASI-EXPERIMENTAL DESIGNS OF THE TSTB PROJECT

Control Mechanism	Design Number 1	2*	3*	4*	5
I. Study Area					
A. Area in which BART has provided improved accessibility	x	x	x	x	x
B. Area in which BART has not affected accessibility	x	x		x	x
II. Study Group					
A. Group (defined in terms of its socioeconomic characteristics) for which BART has provided improved accessibility	x	x	x	x	x
B. Equivalent group for which BART has not provided improved accessibility	x	x		x	x
III. Time Periods					
A. One point in time (i.e., an "after" measurement)	x				x
B. Two points in time (i.e., "before" and "after" measurements)		x			
C. Multiple points in time (i.e., "before," "intermediate," and "after" measurements)			x	x	
IV. Comparison of BART and No-BART Alternatives					x

*These designs can be accomplished by either surveying the same individuals at each point in time or by drawing new samples at each point in time.

2. Comparison of "test" and "control" groups where the groups are defined in terms of their socioeconomic characteristics (e.g., low- and high-income households).

3. Comparison of the data collected at different points in time (i.e., development of time series profiles of changes in behavior and attitudes over the period of introduction and initial operation of "full" BART service).

4. Comparison of synthesized patterns of travel and travel behavior for the operational 1976 BART system as compared to a "no-BART" system. The no-BART system is defined as the most likely transportation system which would have existed in the Bay Area in 1976 had the decision to implement BART not been made in 1962.

There are five quasi-experimental designs which are applicable to answering questions in the TSTB Project:

- Design 1--Analysis of data for one time point (i.e., "post-BART") comparing one area or group served by BART with another not served by BART.

- Design 2--Comparison of one area or group served by BART with another not served, by analysis of data for two points in time (especially one point pre-BART and one point during the period of full BART operation).

- Design 3--Time series analysis of data for one area or group; that is, multiple observations of transportation system and travel behavior and other exogenous events over the period of BART's introduction.

- Design 4--Time series analysis of data observed at many time points comparing one area or group served by BART with another not served.

- Design 5--Comparison of BART with one or more no-BART alternative(s).

These designs are complementary in the sense that they build upon one another and provide increasingly sophisticated (but more difficult to execute) designs.

Design 1--Post-Measurement with Geographic and Functional Control Groups. The basic control mechanisms using Design 1 are proximity to BART (or the change in accessibility resulting from the introduction of BART) and the socioeconomic characteristics of the household. The principal application of Design 1 is to assist in determining why some travelers ride BART and others do not. However, this design will also be used to a limited extent to assess

differences in impedances, attitudes, and travel behavior which can be attributed to proximity to BART service. The proposed TSTB surveys which lend themselves to analysis using this design include the Work Place Survey (No. 4);* the Impedance Trade-Off Survey (No. 6);* and the Special Groups Mobility Survey (No. 7).*

Design 2--Pre- and Post-BART Measurements with Geographic and Functional Control Groups. The basic control mechanisms to be used in Design 2 are proximity to the BART stations (or the change in accessibility resulting from BART) and the socioeconomic characteristics of the households. The principal objective of Design 2, and the surveys which will be conducted in the context of this design, is to ascertain the changes in impedances, attitudes, and travel behavior that can be attributed to the introduction of BART service. The Transbay Surveys (Nos. 2 and 3) can be used to a limited extent to assess the changes in transbay travel patterns (and to some extent transbay highway congestion) that can be attributed to BART. The proposed TSTB surveys which basically involve this design are: (1) the BART Impact Travel Survey (BITS) (Nos. 5a and 5b), and (2) the Transbay Surveys (Nos. 2 and 3).

The BART Impact Travel Survey - I (BITS-I) was conducted in the last quarter of 1973 and the first quarter of 1974 in four survey areas--Fruitvale and Walnut Creek Stations' areas in the East Bay, and 24th Street-Mission and Daly City Stations' areas in the West Bay. These surveys were conducted before the initiation of transbay BART service, although BART service on the East and West Bays was in operation at the time when the surveys were conducted. Two "after" BITS surveys are proposed. Firstly, the original respondents to the BITS-I survey will be recontacted (No. 5a) to determine changes in their attitudes and travel behavior subsequent to the introduction of transbay BART service. Secondly, a new sample will be drawn for a BITS-II survey (No. 5b). Timing of these surveys will allow analysis of the impacts of evening and possibly weekend BART operations.

An interim transbay survey of automobile, BART, and bus travelers in the Bay Bridge corridor was conducted in October 1974, approximately six weeks after the initiation of transbay BART service. The "after" surveys (Nos. 2 and 3) are proposed for the spring of 1976. By that time, BART should have both evening and possibly weekend service in addition to having resolved some of its reliability and car shortage problems.

Design 3--Three or More Measurements Without Control Groups. Measurements at multiple points in time are the only control mechanism used in

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*The number following a survey indicates the survey number which is described in Chapter VII.

Design 3. This design will principally be used to assess the travel patterns and highway congestion changes which can be attributed to BART and to answer the questions relating to "who is using BART." Thus, this is the basic design which will be employed in the analysis of the on-board BART surveys, the traffic and transit ridership count data, and the highway congestion data.

On-board surveys of BART patrons were conducted in May 1973 and May 1974 of riders on the East and West Bay lines; a more comprehensive on-board survey of BART transbay patrons was conducted in October 1974 (No. 2). Two additional on-board surveys are contemplated during the remainder of the TSTB Project; BARTD is planning to conduct an on-board survey in May 1975 which would be similar to the May surveys conducted in the previous years and the TSTB Project is planning to conduct an on-board survey in May 1976 (No. 2). Thus, for some questions included in all of the surveys, data points for five points in time would be available for applying a time series analysis of traveler behavior, traveler characteristics, and trip characteristics of BART patrons.

The other major data bases which will be analyzed using this research design are the historical trends in ridership for BART and bus, and the historical traffic count and traffic congestion data for the various highways within the BART impact area. In some instances, it may be possible to utilize multiple time series regression analyses of travel patterns to ascertain whether changes in trends can be explained in terms of the introduction of BART service and other factors.

Design 4--Three or More Measurements with Geographic and Functional Central Groups. Three basic control mechanisms are used in Design 4--control over time, control by proximity to BART (or accessibility changes induced by BART), and control by the socioeconomic characteristics of the households. Design 4 will principally be used to assess the changes in attitudes, traveler behavior, travel patterns, and secondary travel behavior which can be attributed to BART.

The principal TSTB Project survey that will be analyzed using this design is a telephone survey throughout the BART impact area (No. 1) which may be conducted on as many as four occasions throughout the remainder of the TSTB Project. This areawide telephone survey will utilize some of the questions from, and expand upon, the telephone surveys conducted by BARTD in October 1971 and May 1973. Thus, time series data will be available from before the introduction of BART service until after BART is in full operation for a range of geographic areas with differential BART service and a wide range of households with differing socioeconomic characteristics.

Design 5--Comparison of BART and No-BART Alternatives. This design involves a different form of control than that employed for other designs. It involves a comparison of the travel patterns which arise on the

transportation network following full BART service with the travel patterns which would have arisen if, hypothetically, the decision to build BART had never been made and an alternative transportation system were to exist in the Bay Area in 1976. This comparison of the BART and no-BART alternatives can be used to assess the impacts of BART on impedances, traveler behavior, travel patterns, highway congestion, and to a more limited degree, secondary travel changes, to the extent that simulation models are available or can be developed to detect such changes. A definition of a Generalized No-BART Alternative (GNBA) has been developed[19] and will be refined by MTC and the TSTB Project Team until it constitutes a detailed transportation system description. Analyses of impedances, traveler behavior, travel patterns, and highway congestion assuming the BART and no-BART transportation systems would then be performed in accordance with the approach described in Chapter VI.

VI. RESEARCH METHODS: EVALUATION AND INTERPRETATION

Chapter V described the first stage of a projected two-stage analytical program. It focused on a set of structured statistical analyses, designed to provide empirical findings with respect to the what, who, and to a lesser extent, the why issues of the TSTB Project. This chapter discusses the second stage of the analysis which concentrates on a detailed interpretation of the empirical findings, with particular emphasis on why specific impacts occurred and how a better understanding of these impacts may be utilized to improve subsequent transit system planning both in the Bay Area and elsewhere.*

The analysis is built around the following major elements:

- Development of explanatory behavioral and attitudinal models of travel behavior, based on both objectively measured and perceived travel impedances.

- An assessment of BART's impact on the Bay Area, comparing the benefits and costs of BART with those of the most likely transportation system which would otherwise have evolved in the Bay Area (the no-BART alternative).

- A policy analysis on technology assessment to compare the benefits and costs of BART with those of alternative technologies which are currently feasible (even though they might not be the most likely alternative to BART).

- A policy analysis on technology design to evaluate the benefits and costs of the various BART design features.

- A policy analysis to assess the equity of BART with respect to different groups within the Bay Area population.

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*The distinction between the two modes of analysis is somewhat arbitrary and is made mainly for convenience of presentation. They are clearly closely interrelated. They are not sequential, but rather, they are iterative. The basic descriptive studies detailed earlier provide the foundation for the more complex interpretative exercises outlined here. Conversely, attempts to interpret why particular impacts occurred will, in turn, provide additional insight into the nature of the incidence of the effects identified previously.

- An interpretation of the implications of the TSTB Project's results to ensure transferability of the findings to future transportation decision-making both in the Bay Area and elsewhere.

No-BART Alternative Definitions and Their Analysis Requirements

The mechanism of the no-BART alternative (NBA) is being used in two roles in the program:

- As a quasi-experimental design to provide control for other important variables exogenous to BART (e.g., unemployment, gas prices, automobile prices).

- As a policy assessment technique to enhance the transferability of the BART Impact Program findings.

Both applications need to be considered in defining the NBA and the methods which will be used to analyze the NBA.

The two major components currently proposed for the NBA are:

- Express bus on freeway and local bus service in San Francisco and the AC Transit service area.

- The Southern crossing and extensive associated freeways including a Hunters' Point freeway and a freeway along the Bay serving the southern portion of Alameda County.

Irrespective of the packaging of the NBA components, analysis of the latter requires a full set of regional travel models including trip frequency, destination choice, modal choice, route choice, and trip scheduling components. Analysis of the former could probably be focused on modal choice decisions, recognizing that it would be desirable to include other travel model components.

The land use models that the BART Impact Program plans to use to assess the NBA require estimates of congestion travel times. For this reason, capacitated regional network assignments are required for all NBA analyses, if they are to support the land use model.

Development of Explanatory Behavioral and Attitudinal Models of Travel Behavior

The analyses outlined in Chapter V will provide a description of the nature and incidence of the travel and transportation system impacts flowing from BART's operation. They will also provide some initial evidence of why these impacts occurred, primarily for selected "case study" situations, e.g., particular geographic subareas and subgroups of the population.

These initial, highly focused findings will be extended in the second stage of the analysis to a more general level through the development and application of a series of behavioral and attitudinal travel models. The models will focus on the responses of particular traveler groups to specific system attributes and impedances. Major emphasis will be placed on the impedances presented in Appendix B where appropriate; both objective and perceived impedance measures will be employed.

The models will serve two functions. First, they will be used to make quantitative assessments of the relative importance of selected impedances with respect to traveler behavior and attitudes. Second, they will be used to make quantitative comparisons of probable traveler behavior with respect to BART and alternative no-BART systems.

Three basic types of models will be used in the course of the analysis:

- Regional-scale models for use in comparing regionwide, aggregate travel and transportation system performance resulting from BART with models of those that might have occurred as a result of one or more no-BART alternatives.

- Detailed logit type models of disaggregate travel behavior, based on observed travel patterns in selected corridors and market segments and objective measurements of "augmented" system impedances.

- Attitudinal models, based on estimates of traveler attitudes toward both objective and perceived measurements of travel impedances; these models will again focus on selected corridors and market segments.

The TSTB Project will only develop the second and third types of models. The first type of model--the regional travel model system--is currently being developed by MTC. The three types of models will be designed to complement one another, with each focusing on issues that can be only partially addressed by the others. Model development will be coordinated with the work of the University of California's Travel Demand Forecasting Project,* which is sponsored by the National Science Foundation, and with an on-going project to refine MTC's regional-scale travel model system.

Regional Travel Models. These models are required to:

- Make regional-scale comparisons of the BART and no-BART alternatives.

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*The major emphasis of the Travel Demand Forecasting Project is upon home-to-work travel; development of nonwork models will have to be undertaken as part of the TSTB Project.

- Compare the BART system with any no-BART alternative involving the Southern crossing and its associated highways.

- Provide system-sensitive (i.e., capacitated) network travel times based on capacitated highway network assignments for use as input to the land use forecasting model to be used in the BART Impact Program Land Use Project.

The regional models need to be system sensitive with respect to the full range of traveler decisions: trip frequency, destination choice, modal choice, route choice, and trip scheduling. Capacitated network assignments are required to provide congestion travel times for the land use model. Because they will be applied in a regional context, these regional models will probably incorporate a relatively limited number of transportation service variables (e.g., travel time, travel cost).

Disaggregate Logit Formulations. A set of disaggregate logit formulations will be developed by the TSTB Project and used to (1) analyze and explain the pattern of patronage observed for BART and its competing and complementary modes; (2) create equivalent travel estimates for comparison of BART and several no-BART alternatives, with particular emphasis on selected market segments; and (3) provide a transferable methodology that advances the current "state-of-the-art" of travel modeling.

Conventional regional travel models will not adequately reflect important differences in the quality of the service provided by BART relative to other transit services--particularly buses. To reflect these differences, it is necessary to "augment" the characterization of the transit and highway services with respect to such variables as reliability, security, safety, seat availability, and parking availability.

The crucial issue with regard to the transferability of the models is the structure and application of the models, not the actual parameters estimated. In the sense that the logit models are an advancement of the state-of-the-art, they may be considered more transferable than the more conventional regional travel models.

Logit models will be developed to predict the following types of travel decisions (in approximate order of priority): (1) modal choice, (2) trip frequency, and (3) trip timing. To the extent feasible, the question of destination choice will also be examined. Development of a modal split model is of particular importance, since approximately 90% of BART's initial ridership was diverted from other modes. Emphasis will be placed on the development of models for particular traveler groups (defined by income category and other variables).

The TSTB Project will, if possible, utilize the logit type home-to-work modal split model being developed by the Travel Demand Forecasting Project, rather than develop its own estimations. If it proves impossible to utilize the Travel Demand Forecasting Project's modal split model to achieve the objectives of the TSTB Project, new logit type home-to-work modal split models will be estimated. A nonwork modal split model and models for other traveler decisions will be estimated by the TSTB Project.

Inasmuch as application of logit models requires networks containing the augmented measures and thereby imposes additional data requirements, these models would not be applied throughout the region. Rather, they would be applied in selected corridors or markets. It would be desirable if the logit models with augmented measures were applied in conjunction with the regional models to ensure provision for a full range of travel models and to allow estimation of equilibrium travel conditions. Alternatively, forms of the logit models could be implemented with reduced, more conventional measures of service for use in the regional models.

Appropriate market segments for calibration of logit models would be: (1) transbay travel, (2) Caldecott Tunnel travel, (3) home-to-work travel, and (4) BART Impact Travel Survey areas travel. Their selection is predicated primarily on grounds of (1) data availability,* (2) significance of BART's role within the corridor, and (3) potential for analytical "control" and meaningful comparison of the BART and no-BART alternatives. Nonwork and work models (including a home-to-work modal split model, if necessary) would be developed for each corridor. They will be based on travel data developed as part of the October 1974 transbay survey and the proposed Caldecott Tunnel survey (Surveys 2 and 3 on page 70) plus network data developed for selected interchanges.

A set of work-trip models (including a modal split model, if necessary), will also be developed for home-to-work travel based on data derived from the proposed workplace survey (Survey 4 on page 70). Finally, logit type models could be calibrated using the data acquired in the four BART Impact Travel Survey (BITS) (Survey 5 on page 70) areas.

Attitudinal Models. A complementary set of attitudinal models will be developed, designed to (1) extend the logit type analyses by focusing on issues that the logit models cannot completely address, (2) permit quantitative assessment of the perceptions and attitudes of Bay Area residents, and (3) provide transferable methodology that advances the current state-of-the-art of demand modeling. The analysis will consider both users and

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*This point is discussed in more detail in Chapter V. The major data limitation is the lack of adequate, current origin-destination travel data.

nonusers of BART. It will also assess changes in the attitudes of Bay Area residents toward the system as it matures over time, with particular emphasis on perceived as opposed to objective measurements of system impedances.

The attitudinal modeling will be conducted in two stages. The first will focus on the use of standard psychometric scaling techniques to assess the relative importance of different system attributes to particular user (or potential user) groups. The second will employ conjoint analysis techniques to develop a set of attitudinal "trade-off" models. These will be used both in estimating potential traveler response to variations in BART's existing attributes and also for comparisons of the BART and no-BART alternatives.

The motivation for undertaking a complementary attitudinal model development activity is threefold.

First, it permits direct examination of evolving public perceptions and attitudes toward BART design features and operating practices. The resultant information will both complement the behavioral analyses outlined above, and also be of value to future transit planning in the Bay Area and elsewhere. The issues involved may only be partially addressed using the logit approach.

Second, a trade-off formulation can explicitly incorporate the effects of "soft" or qualitative variables--e.g., ride quality--which can only be somewhat tenuously incorporated by the more conventional logit structures. It provides an approach for analyzing a wider range of no-BART alternatives than would otherwise be possible. This approach is more economical than conventional procedures, because it does not require the development of detailed (and costly) networks.

Third and finally, development of models of this type represents an area of methodological innovation that appears particularly appropriate to the TSTB Project and complements, rather than duplicates, the activities of the Travel Demand Forecasting Study. If proven successful, it will provide a transferable methodology having considerable potential application in other areas.

No attempt will be made here to discuss in detail the procedures involved in either mode of attitudinal analysis. An illustrative example of the use of trade-off analysis is provided elsewhere.[20]

The attitudinal modeling work will focus mainly on a limited number of specific corridors and market segments. In this case, they will be:

- Transbay corridor
- Trips originating in BART Impact Travel Surveys (BITS) I and II survey areas

For the transbay corridor, the models will be calibrated on data developed as part of the October 1974 transbay survey (Surveys 2 and 3 on page 70). The

main focus in this instance will be on attitudinal scaling models.* A series of special purpose impedance trade-off surveys, will be conducted in the BITS study areas (Survey 6 on page 70). These will focus on traveler responses to alternative mixes and levels of system impedances. The models will be directed specifically to issues germane to the comparisons of the BART and no-BART alternatives to be made in each area.

In addition, comparisons of changing attitudes and perceptions toward BART over time will be made, using as input a sequence of BART impact area telephone surveys (Survey 1 on page 70). These analyses will focus on the evolution of public attitudes toward BART over approximately a five-year period commencing prior to the inception of any BART service.

Analyses will be stratified according to a set of major market segments. Selection of the final impedances to be incorporated in the trade-off model will be based on results of the initial attitudinal scaling work. Attention will be focused mainly on measures which cannot be as conveniently incorporated in the logit formulations--e.g., activity while traveling, quality of ride, security, safety, etc.

Impact Assessment Using the BART and No-BART Alternatives

Impact assessment based only on before and after comparisons, no matter how carefully controlled, is subject to several serious methodological and interpretative shortcomings.** One approach to surmounting some of these problems is to redefine the meaning of "impact." That is, not to express it in terms of a before-and-after comparison, but rather in terms of a comparison of BART's impacts with those that might be expected to have occurred had some alternative system(s) been built instead of BART. Such an analysis is the essence of the comparison of the BART and no-BART alternatives. Methodologically, it is similar to a comparison of two or more alternative systems in a planning study. There are, however, some important differences.

Of these, the most significant is the increased quality of information available for one alternative, i.e., BART. Desirably, conventional patronage

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*These same data provide the basis for much of the initial attitudinal analysis performed during the first stage of the analytical work program. The purpose here is to extend and refine these analyses.

**See Chapter V.

estimating techniques should, therefore, be modified to take advantage of the increased quality of available information.

In the present case, this will be accomplished in three ways. First, the regional travel model system developed by MTC will be used to construct regional travel estimates both for BART and for one or more no-BART alternatives. Second, data on the BART experience will be used to calibrate and validate a series of logit and attitudinal travel models, explicitly responsive to those issues most relevant to the BART/no-BART comparison. Third, in addition to the regional-scale analysis outlined above, attention will be directed to a more detailed study of a limited set of corridors and/or market segments within which BART plays a major role, and where a no-BART alternative might be expected to result in significantly different travel behavior.

The logit and trade-off types of models of traveler behavior developed by the TSTB and probably the Travel Demand Forecasting Projects will be used to perform the latter forms of analysis. The three-pronged approach suggested here is preferable to exclusive reliance on a more conventional regional-scale simulation for several reasons. The most significant of these are (1) the error variance associated with regional-scale analyses may well damp-out many significant BART/no-BART differences; (2) most BART/no-BART differences are likely to be highly localized affecting specific traveler groups; (3) development of regionwide projections is likely to be extremely costly, requiring both collection of up-to-date origin-destination data and extensive, detailed network coding; and (4) development of regionwide projections desirably requires system-sensitive land use projections which are not essential at a localized level. An example of the procedures involved in the application of the trade-off model to the comparison of BART/no-BART travel for a particular corridor is provided elsewhere.[20]

For both the regional-scale and the detailed analyses, the actual comparisons will be based on one or more no-BART alternative(s) being developed under a separate element of the Bart Impact Program.[19] These alternative(s) will be converted into a quantitative system description suitable for use in conjunction with travel model analyses. For the regional-scale analyses, this will involve the development of regional networks representing the NBA. For the logit model analyses, this will take the form of a detailed network (including augmented attribute measures) for each selected corridor. For the trade-off model, it will take the form of a simpler, quantitative description of the service levels associated with each alternative for each corridor. This description may utilize available network data, together with additional non-network information.

The outputs of the analysis would be estimates of 1975 ridership on transit and automobile for the BART and no-BART alternative(s). Estimates would be developed for (1) modal choice, (2) trip frequency, and (3) trip timing.

If feasible and appropriate, estimates will also be made of variations in destination choice.*

The analyses using the logit and attitudinal models will focus on the same set of corridors and market segments used for model development; that is:

- Transbay corridor
- Caldecott Tunnel corridor
- Home-to-work travel
- Selected origin-destination pairs, with origins in the BITS I and II study areas

The estimates will be stratified by user characteristics, to the extent that the calibrated models reflect differences in behavior between different groups.**

The time frame of the NBA analysis is related to the two objectives of the analysis. Because development decisions in anticipation of BART began in the early 1960s, the land use model must begin its recursive operation at that time. From the perspective of the quasi-experimental design for comparing the BART and no-BART alternatives, it is probably sufficient to operate the model system in recursive five-year periods through 1980 or 1985. However, from the perspective of the policy analyses described below, which need to consider time streams of benefits and costs, it is probably necessary to operate the model system in recursive five-year periods, through 1990 or 1995.

Technology Assessment of BART and No-BART Alternatives

At present, only a single no-BART alternative is being developed. This is defined as the most likely transportation system which would have existed in the Bay Area had the decision to build BART not been implemented in 1962. Comparison of the impacts of BART to those of this most likely alternative is important as a form of control for use in assessing BART's impacts on the Bay Area. From the perspective of the policy issue of assessing transportation technology, however, it is also of interest to assess the relative benefits and costs of BART as compared to other systems that might have been implemented. In the context of current policy concerns, there are several no-BART alternatives that are of interest to decision-makers and planners; these include: (1) express buses on exclusive lanes; (2) low capital cost options

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*The treatment of destination choice on a meaningful, consistent basis significantly compounds the estimation problem. A decision on whether or not to include this element in the analysis will be based on the results of the transbay and related surveys conducted in late 1974/early 1975.

**A more detailed definition of the structure of the BART/no-BART analyses will be made once the characteristics of the no-BART alternative have been fully determined.

involving staggered work hours and car pooling; (3) automobile-oriented solutions involving additional major highway facilities, particularly an additional transbay bridge; (4) a light rail transit system; and (5) a system in which BART is implemented throughout the Bay Area, including routes serving Marin and San Mateo Counties.

A comparison of the BART and no-BART alternatives entails contributions from all elements of the BART Impact Program; the following discussion focuses on the aspects that will be accomplished by the TSTB Project. The attributes of the various no-BART alternatives, particularly cost and energy consumption, will be assessed. Traveler behavior in response to the alternatives will be assessed using MTC's regional travel analysis model system and the logit and attitudinal models developed in the TSTB Project. MTC's regional travel analysis model system will be used to assess the overall regional impacts of the no-BART alternative and to provide congestion travel times for the land use forecasting model being developed by the Land Use and Urban Development Project.

The logit model will be used to assess traveler response for three important travel market segments: (1) transbay travel, (2) Caldecott Tunnel corridor travel, and (3) home-to-work travel to the CBDs of San Francisco and Oakland and to a third non-CBD employment site. The attitudinal model will be used in a selected set of subareas of the region to perform very detailed case studies of traveler responses to the various no-BART alternatives. The results of the analyses conducted by the TSTB Project and appropriate inputs from other BART Impact Program projects will be arrayed in a form that allows a display of the transportation benefits and the costs of the various no-BART alternatives as compared to BART. This is not intended to imply a formal cost-benefit analysis. Rather, it implies a consolidation of the impact findings developed earlier which addressed specific aspects of travel behavior and system performance into a series of aggregate findings, relevant to the system as a whole.

Technology Design - Assessment of BART Design Features

This policy analysis focuses on the benefits and costs of specific elements of BART's design. Chapter I presented a preliminary list of the BART design features to be considered in this analysis. Additional BART design features may be added to this list, based on the interim findings of this study.

The costs of the various design features of BART will be obtained from the cost analyses conducted by the TSTB Project. The traveler benefits of these design features will be based on sensitivity analyses employing the logit and attitudinal travel models developed by the TSTB Project. Where possible, both models will be applied to assess traveler response to a particular change in a design feature. In some cases, only a particular model can be used to assess the sensitivity of traveler behavior to a particular design feature because of the formulation of the model. The benefits and costs of each of the BART design features considered in the analysis will be organized in an evaluation framework, augmented as appropriate by the products of other BART Impact Program projects.

Equity of BART Benefits and Costs

The issue of the equity of BART's benefits and costs underlies the entire analysis. This issue includes the questions of (1) whether or not the benefits and disbenefits of the system are distributed equitably across all population groups, and across all market segments; and (2) the issue of the geographic or social incidence of service improvements versus the incidence of costs, either direct (e.g., fares) or indirect (e.g., taxes).

Apart from the BART Transbay Tube, which is paid for by revenues from the Bay Bridge, the capital costs of BART are paid for by the taxpayers of the BART impact area in the form of property taxes and a sales tax. In addition, the taxpayers currently support approximately two-thirds of the BART operating budget. The Economics and Finance Project will assess the incidence of the taxation to support the BART system with respect to various subgroups of the population.

Insofar as there is a community contribution to the construction and operation of BART, the travelers who use BART benefit from this community contribution. The characteristics of the population of travelers who benefit can also be assessed in terms of their income, ethnic identification, and geographic location. By comparing the incidence of the taxation used to support BART to the incidence of the benefits of BART, it is possible to assess the social equity of the BART system given the context of this set of definitions.

Even if the results indicated an apparently equitable benefit-cost pattern, it might still be desirable to assess whether BART had contributed to bringing about greater equality between a disadvantaged group and the general population. For example, because BART was designed with the handicapped in mind, those people have opportunities for travel that were probably not available previously. Clearly, a benefit-cost assessment of the handicapped versus the nonhandicapped would show that the latter were paying relatively more for the system's special handicapped features than the benefits that they derived from them. However, because the handicapped presumably now have improved mobility, BART's improvements which were designed for accomodating the handicapped, have potentially helped in bringing the handicapped closer to equality with the nonhandicapped. It is in this sense that the study would be designed to assess the effects of BART on decreasing the disparity between minorities and whites, between the handicapped and the nonhandicapped, and between any other disadvantaged groups and the population as a whole.

Interpretation of Findings to Ensure Transferability

One of the primary objectives of the BART Impact Program is to provide guidance for future decision-making, both within the Bay Area and elsewhere--that is, to interpret the impacts associated with BART in terms of their implications for future planning and decision-making. This is the subject of the final phase of the analysis program. In interpreting BART's impacts

to ensure transferability, at least two important points need to be borne in mind.

First, the impacts must clearly be interpreted in the context of the conditions under which they occurred. This includes both the particular physical, demographic, and social characteristics of the Bay Area and the sequence of decisions that led to the construction and operation of BART in its current form. Some of these conditions are unique to the Bay Area, others less so. In order for the findings to be meaningful to other areas, such unique features must (to the extent possible) be identified and their influence accounted for. Equally important, provisions must be made for identifying clear commonalities between Bay Area conditions and those existing elsewhere. This can be only partially achieved quantitatively--e.g., through the use of small-area demographic data, transportation service levels, etc. Much of the analysis must necessarily be subjective, depending for support upon quantitative evidence of similar conditions, but not relying exclusively on such data. A final thrust of the analysis program will be devoted to identifying (1) those aspects of BART that tend to make its experience (and impacts) unique, and (2) a data base on Bay Area conditions which will facilitate interpretation and comparison of BART's observed impacts with those anticipated in other areas.

Second, it is clear that the range of findings on BART, which will be of interest both locally and nationally, is likely to be extremely broad. It will span issues ranging from areawide impact and overall system planning and operation to highly specific questions concerning individual BART design features and isolated impacts. Many, but by no means all, of these issues will have been anticipated in the course of the BART Impact Program design. Some, particularly policy issues of concern to the federal government, are likely to emerge only as the program progresses. Provision, therefore, must be made not only for interpreting those impacts of major concern, but also for responding to particular (and potentially somewhat unrelated) issues as they arise. This question is being addressed by MTC through the BART Impact Program transferability activity. The role of the TSTB Project will be to support this undertaking by providing data, interim research findings, and interpretative recommendations as requested by MTC.

VII. RESEARCH METHODS: DATA REQUIREMENTS

This chapter discusses the measurements that will be conducted during the course of the TSTB Project to test the validity of the questions described in Chapter III. An integrated data acquisition program is proposed which is explicitly designed to implement the analysis approaches defined in Chapters V and VI. Because of the importance of assessing BART's impacts on disadvantaged segments of the Bay Area population and because of the difficulties of measuring impacts on disadvantaged groups using conventional methodological approaches, special methods will be used to assess BART's impacts on these groups. The special methods are also described in this chapter.

Measurement of Transportation System Attributes

Six basic attributes of the transportation system were specified in the conceptual framework discussion presented in Chapter II. These are: (1) routes, (2) stations and terminals, (3) equipment (including the parameters of the technology), (4) schedules, (5) supply costs, and (6) energy consumption. In some cases, a number of additional attributes can be specified within a general category; for example, vehicle capacity, maximum vehicle speed, acceleration-deceleration capabilities, and equipment age are included in the equipment attribute.

In general, these attributes will be measured on a historical basis for all of the transit services that operate in the BART impact area as well as for the automobile mode. As changes in the attributes occur, the data files will be appropriately updated. However, with the exception of automobile passengers or car poolers, the attribute of schedule has no meaning for the automobile mode, and consequently, data will not be obtained on this attribute for automobiles.

Data on the attributes will be obtained for the following transit services in the BART impact area: BART, AC Transit (which operates buses within the East Bay and from the East Bay to downtown San Francisco), and MUNI (which operates buses, electric trolley buses, street cars, and cable cars within San Francisco). In addition, a number of other transit services have operations which are of relevance in the BART impact area, although these are on a much smaller scale. As necessary for the purposes of the TSTB Project, data on the attributes of some of these other transit operations will also be obtained. These operators include Northgate Transit (which provides service to Daly City), Greyhound (which provides some service in the Mission Street corridor, northern San Mateo County, and Contra Costa County), Humphrey Go-BART (which provides feeder service to the Berkeley BART Station), and Peerless Stages (which provides service between Oakland and San Jose). Finally, the attributes of taxi services in the BART impact area and the jitney service along San Francisco's Mission Street will be monitored, as necessary, and to the extent that appropriate data can be readily obtained.

Measurement of Transportation System Impedances Perceived by Travelers

The 30 impedances listed in Appendix B will be measured during the course of the TSTB Project, insofar as they affect traveler behavior in response to BART.

In general, two approaches are available for measuring the level of an impedance: (1) the traveler's perception of the level of a particular impedance and (2) a physical measurement of the level of the impedance. Perceptual measurement is obtained through a survey, whereas physical measurement is an engineering assessment of the level of the phenomenon. Both perceptual and physical measurements of impedances will be conducted during the course of the TSTB Project as outlined in the measurement program of the TSTB Project presented in Exhibit 13. The 30 impedances for which BART is expected to induce changes are listed in the left-hand column of the exhibit. Measurements will be obtained for each of the three principal modes operating in the BART impact area--BART, bus, and automobile. Since there are actually two principal bus operators (MUNI and AC Transit) in the BART impact area, the perceptual and physical measurements will have to be obtained for both, since the services provided by each differ considerably.

In general, a perceptual measurement will be obtained for each impedance for each of the modes, unless the particular impedance is not applicable to a particular mode. The perceptual measurements will be obtained at those points in time when the surveys are conducted. Multiple perceptual measurements of some of BART's impedances (for example, reliability and safety) will be obtained to measure the changes in travelers' perceptions of these impedances as BART service is improved.

A description of the time frequency and spatial extent of the physical measurements to be performed during the TSTB Project is presented in Exhibit 13. The physical measurements are a function of the definitions of the impedances. In some cases, the measurement will require the analysis of various data in the files of an operating agency; for example, information on parking lot utilization at the BART stations is available in BART's files. In other cases, primary data collection will be involved. When the appropriate measurement can be obtained from analysis of data in agency files, multiple observations for the BART impact area are planned. In some cases, the number of observations and the spatial extent will be reduced because of the resources required to reduce the data available in the agency files. In those cases where physical measurements are required, resource limitations of the TSTB Project dictate that the measurements be performed for a single point in time and for a segment of the BART impact area.

EXHIBIT 13

DATA ACQUISITION PROGRAM FOR TRANSPORTATION SYSTEM IMPEDANCES

Impedance	BART			Bus			Automobile		
		Physical Measurement			Physical Measurement			Physical Measurement	
	Perceptual Measurement[a]	Time Frequency of Observation[b]	Spatial Extent of Observation[c]	Perceptual Measurement[a]	Time Frequency of Observation[b]	Spatial Extent of Observation[c]	Perceptual Measurement[a]	Time Frequency of Observation[b]	Spatial Extent of Observation[c]
Impedances to be included in Travel Models (Priority 1)									
1. Total door-to-door travel time	X	S	R	X	T	R	X	T	R
2. Time spent walking	X	S	R	X	T	R	X	T	R
3. Time spent waiting as a result of schedule delay	X	S	R	X	T	R	X	T	R
4. Out-of-pocket cost of travel (in the short run)	X	S	R	X	T	R	X	T	R
5. Total cost of travel (in the long run)	--	--	--	--	--	--	X	T	R
Impedances to be studied in-depth (Priority 2)									
6. Effort involved in transferring between vehicles	X	S	S	X	S	S	--	--	--
7. Reliability of on-time arrival (in normal circumstances)	X	M	R	X	M	R	X	S	S
8. Reliability of on-time arrival (in abnormal circumstances)	X	M	R	X	M	S	X	--	--
9. Comfort of the vehicle seat and surroundings	X	S	S	X	S	S	X	S	S
10. Security from personal attack or unpleasantness	X	M	R	X	M	S	X	M	S
11. Safety from vehicular accidents	X	M	R	X	M	R	X	M	R
12. Flexibility of being able to combine secondary trip	X	--	--	X	--	--	X	--	--
13. Flexibility of accommodating unusual times for the return trip	X	T	--	X	--	--	X	--	--
14. Crowding of the vehicle	X	M	S	X	M	S	X	--	--
15. Availability of seats	X	M	S	X	M	S	X	--	--
16. Probability of a prolonged cessation of service (e.g., a transit strike)	X	--	--	X	--	--	X	--	--
17. Parking availability	X	M	R	X	--	--	X	M	S

EXHIBIT 13 (cont.)

DATA ACQUISITION PROGRAM FOR TRANSPORTATION SYSTEM IMPEDANCES

Impedance	BART			Bus			Automobile		
		Physical Measurement			Physical Measurement			Physical Measurement	
	Perceptual Measurement[a]	Time Frequency of Observation[b]	Spatial Extent of Observation[c]	Perceptual Measurement[a]	Time Frequency of Observation[b]	Spatial Extent of Observation[c]	Perceptual Measurement[a]	Time Frequency of Observation[b]	Spatial Extent of Observation[c]
Impedances to be studied on exploratory basis (Priority 3)									
18. Privacy and the ability to avoid undesirable social contact	X	--	--	X	--	--	X	--	--
19. Ability to read the paper or work	X	--	--	X	--	--	X	--	--
20. Ability to listen to the radio, sleep, sightsee	X	--	--	X	--	--	X	--	--
21. Freedom to smoke	X	S	S	X	S	S	X	--	--
22. Noise level within the vehicle	X	S	S	X	S	S	X	S	S
23. Smoothness of the ride (i.e., vibration level within the vehicle)	X	S	S	X	S	S	X	S	S
24. Protection from the weather	X	S	S	X	S	S	X	--	--
25. Aggravations of driving in congested traffic conditions	--	--	--	--	--	--	X	--	--
26. Vehicle decor and cleanliness	Z	--	--	X	--	--	--	--	--
27. Air quality and temperature within the vehicle	X	S	S	X	S	S	--	--	--
28. Method of payment for transportation service	X	S	S	X	--	--	X	--	--
29. Station decor and cleanliness	X	--	--	--	--	--	--	--	
30. Identification with travel environment and other travelers	X	--	--	X	--	--	X	--	--

a. Perceptual Measurement: X - Indicates that observation will be made.
-- - Indicates that no observation will be made.

b. Time Frequency of Observation: S - Observation at single point in time.
T - Observation for two points in time ("before" and "after" BART).
M - Observation at multiple points in time.

c. Spatial Extent of Observation: R - Observation to be obtained for regional BART impact area.
S - Observation to be obtained for segment of BART impact area.

Measurement of Traveler Perceptions, Attitudes, and Behavior

The basic measurement device which is used to obtain information on traveler perceptions, attitudes, and behavior is a questionnaire survey. Four basic types of questionnaire surveys will be used in the TSTB Project: (1) home interview survey, (2) telephone survey, (3) on-route survey, and (4) work place survey. A discussion of the advantages, disadvantages, and costs of each of these survey approaches is presented in the detailed research plan.[4]

An integrated survey research program for the TSTB Project is presented in Exhibit 14.* This survey research program is explicitly designed to provide measurements of perceptions, attitudes, and traveler behavior within the context of the analysis approaches discussed in Chapter V and VI. The three principal components of the proposed survey program are:

- Measurement of regional traveler behavior and attitudes.
- Measurement of perceptions, attitudes, and behavior of travelers within the following important BART travel market areas.
  - Transbay travelers.
  - Travelers from central Contra Costa County to the East and West Bays through the Caldecott Tunnel screenline.
  - Work travelers in downtown San Francisco and Oakland and one suburban location.
- Measurement of traveler perceptions, attitudes, and behavior of important groups of BART impact area residents; these groups will be defined:
  - Geographically so as to obtain representation from all of the ethnic and income groups residing in the Bay Area.
  - With a special focus on disadvantaged groups (see Exhibit 11).

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*As with all other proposals presented in this research plan, this survey program must be regarded as tentative with regard to both timing and content. The program may subsequently be modified to reflect a number of influences including preliminary research results, experience with early surveys, and budgetary constraints.

EXHIBIT 14

INTEGRATED TSTB SURVEY PROGRAM

	1974		1975				1976			
	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Measurement of Regional Travel Behavior and Attitudes										
1. Telephone Survey in BART Impact Area				X		X				X
Measurement of Travel Behavior and Attitudes of Travelers within Important BART Travel Market Areas										
2. On-Board BART Questionnaire Mailback Survey		X Transbay Only						X Systemwide		
3. En route Automobile and Bus Questionnaire Mailback Survey for Transbay and Caldecott Tunnel Travel		X Transbay Only						X Transbay and Caldecott Tunnel		
4. Work Place Survey in Central Business Districts (CBD) of San Francisco and Oakland and One Non-CBD Location						X				
Measurement of Travel Behavior and Attitudes of Important Groups of BART Impact Area Residents										
5. Surveys in Four BART Impact Travel Survey (BITS-I) Areas										
a. Telephone Recontact of BITS-I Respondents						X Telephone BITS-I Recontact				
b. Home Interview Survey of New Sample								X Home Interview BITS, New Sample		
6. Home Interview Impedance Tradeoff Survey								X		
7. Disadvantaged Groups Special Mobility Surveys				X						

Thus, the survey program provides for a range of measurements--from a relatively crude set of areawide measurements to a very detailed and precise set of measurements for particular market segments and important groups of BART impact area residents.

Special consideration is given in this survey program to assessing BART's impacts on the disadvantaged groups identified in Chapter IV. Several of the surveys (Nos. 5a, 5b, and 7) will be specifically designed to obtain a larger proportion of respondents from disadvantaged groups than the overall representation of these groups in the Bay Area's population. In the remaining surveys, the disadvantaged groups will be sampled at the same rate as their overall representation in the population being sampled. Special measures will be taken, however, to reduce the response bias of disadvantaged groups (that is, the bias in the survey resulting from a lower survey response rate by disadvantaged groups than by the population as a whole). For example, in the telephone survey (No. 1), interviews will, if necessary, be conducted in Spanish (i.e., Mexican and Central American dialects) and Chinese (i.e., Cantonese dialect) to reduce the response rate bias caused by communications barriers.

Survey 1--Telephone Survey Within BART Impact Area. The telephone survey will be used to obtain areawide measurements of BART's impacts at a relatively low cost per interview. These data on regional traveler perceptions, attitudes, and behavior will be used to monitor regional trends in order to guide and interpret the more detailed and specific data acquired during the remainder of the survey program. The survey will be modeled on the two areawide telephone surveys which were completed by BARTD in October 1971 and May 1973. However, both the sampling plan and the questionnaire design will be significantly modified to fulfill the TSTB Project objectives. Thus, a series of five areawide measurements of relatively crude measures of traveler behavior and attitudes will be available for assessing BART's impacts in a regional context. These surveys will principally be analyzed in the context of Design 4 which was discussed in Chapter V.

Survey 2--On-Board BART Questionnaire Mailback Survey. These surveys will principally be used to obtain information on traveler perceptions, attitudes, and behavior for a very large sample of BART travelers. This data base will be valuable for answering questions concerning who is riding BART.

BARTD conducted on-board mailback surveys on the system in May 1973 and May 1974 and will conduct a similar survey in May 1975. The BARTD surveys contain a smaller set of questions than the surveys planned for the TSTB Project, but any questions that are used on both surveys will be compatible. Thus, it will be possible to measure time series changes in the characteristics of BART riders over a three-year period between 1973 and 1976. Further, it will be possible to assess changes in BART Traveler perceptions and attitudes between fall 1974 and spring 1976. This series of on-board BART surveys will principally be analyzed using Design 3 which was discussed in Chapter V.

Survey 3--En Route Automobile and Bus Questionnaire Mailback Survey for Transbay and Caldecott Tunnel Screenlines. Transbay travel across the Bay Bridge screenline is of major interest to the TSTB Project for several reasons. The Bay Bridge and its approaches constitute one of the most congested links in the entire highway system of the Bay Area and anticipated future increases in travel and congestion on this link were a major justification for constructing BART. Approximately 40% of total BART usage involves the transbay link. Thus, an analysis of transbay BART travel is of substantial interest to the TSTB Project.

Further, the Bay Bridge cordon is one of the few situations in the Bay Area where it is possible to conduct a large sample questionnaire mailback survey of the universe of automobile and bus travelers. A questionnaire mailback survey of transbay automobile and bus passengers was conducted in fall 1974, and a second survey of this type is planned for spring 1976 to measure changes in traveler perceptions, attitudes, and behavior. A sufficient period of time will have elapsed before the second survey to allow stabilization of traveler responses to the introduction of BART service. These two surveys will largely be analyzed using Design 2 which was discussed in Chapter V.

It would be desirable to obtain a large sample of data on traveler perceptions, attitudes, and behavior for all travel markets. However, the practicalities of large sample on-route surveys makes two corridors particularly amenable to survey. These are the Bay Bridge and Caldecott Tunnel. The transbay travel market is one of the most interesting travel markets in the Bay Area, but has the disadvantage that it is in some respects unique because of Bridge traffic congestion; the fact that the destinations are concentrated in downtown San Francisco with its relatively high parking costs and traffic congestion; the psychological barrier of the Bridge, and the fact that the average trip length is relatively long. The Caldecott Tunnel screenline is the only other situation in the BART impact area where it is possible to conduct a questionnaire mailback survey of the universe of automobile drivers* and bus riders** in a given BART corridor at a reasonable cost.

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*The methodology of the en route automobile survey on the Caldecott Tunnel screenline will of necessity be different from the en route automobile survey on the Bay Bridge screenline, since there are no toll booths at the Caldecott Tunnel where questionnaires can be handed out. Rather, automobile license plates will be photographed, the addresses of the automobile owners looked up using the files of the Division of Motor Vehicles, and questionnaires mailed out.

**Because of the reduction in patronage following the initiation of transbay BART service, Greyhound is reducing its service to central Contra Costa County. Hence, there may be no bus service through the Caldecott Tunnel at the time this survey is conducted.

Surveying the Caldecott Tunnel screenline has the advantage of providing for detailed multimodal travel data for the BART Concord Line corridor--the most successful of the four BART lines in terms of its patronage attraction. For this reason, an on-route survey of automobile and bus travelers on the Caldecott Tunnel screenline in the spring of 1976, is proposed to run concurrent with and be compatible with the on-board BART survey.

Survey 4--Work Place Survey in Central Business Districts of San Francisco and Oakland and One Non-CBD Location. A significant proportion of total travel on BART is for work travel to the CBDs of Oakland and San Francisco; this is by far the single most important travel market segment using BART at present. For this reason, it is important to assess the perceptions, attitudes, and behavior of home-to-work travelers, both to the central business districts (CBDs) of Oakland and San Francisco as well as to other non-CBD locations. The work place survey provides a relatively low cost mechanism for obtaining a large sample of measurements of the attitudes, perceptions, and behavior of home-to-work travelers. This survey would be conducted in the fall of 1975 (or in spring 1976, if the survey design cannot be completed satisfactorily by fall 1975) and would be designed to be compatible with the on-board BART and on-route automobile and bus surveys. This survey would largely be analyzed using Design 1 which was discussed in Chapter V.

Survey 5--Surveys in Four BART Impact Travel Survey Areas. The most detailed "before" surveys of traveler perceptions, attitudes, and behavior which are available for selected groups of residents within the BART impact area are the BART Impact Travel Survey (BITS) data. Thus, it is extremely important that a corresponding compatible set of "after" data be obtained. The BART Impact Travel Survey - II (BITS-II) will have two components: (1) a telephone recontact in fall 1975 of the respondents to the BITS-I survey, and (2) a home interview survey of an entirely new sample in the four BITS survey areas in the spring of 1976.

This telephone recontact of the BITS-I respondents would be integrated with a similar survey activity planned by the Travel Demand Forecasting Project. It is not possible, however, to rely solely upon a panel approach to the "before" and "after" analysis of the BITS survey design inasmuch as a significant proportion of the respondents to the BITS-I survey will have changed their residence and/or their job locations in the two-to three-year period between the BITS-I and BITS-II surveys.

For this reason, the BITS-II survey which is planned for spring 1976 will be conducted for an entirely new sample of 400 respondents in each of the four survey areas. This new sample will be drawn using the same sample selection criteria as were used to draw the BITS-I sample. The two surveys will largely be analyzed using Design 2 which was discussed in Chapter V.

Survey 6--Home Interview Impedance Trade-Off Survey. Two travel model approaches are described in Chapter VI for explaining traveler behavior in response to BART: (1) explanatory behavioral modeling of perceived impedance measures and (2) behavioral modeling of objectively measured impedance measures. Survey 6 will be conducted to obtain the necessary data for calibrating the former of these models. The survey will be conducted in spring 1976 when it is anticipated that traveler perceptions and attitudes with respect to BART will have stabilized to a reasonable extent. When the detailed design of the spring 1976 surveys is accomplished, careful consideration will be given to piggybacking the home interview impedance trade-off survey onto the home interview BITS-II survey.

Survey 7--Disadvantaged Groups Special Mobility Surveys. These are special surveys which will be conducted in the TSTB Project to assess BART's impacts on the perceptions, attitudes, and travel behavior of particular disadvantaged groups within the Bay Area. At a minimum these groups will include: (1) low-income residents, (2) ethnic minorities, (3) the physically handicapped, (4) the elderly, (5) youth, and (6) other individuals with a low automobile availability. The next section of this chapter is devoted to a discussion of the special groups surveys and analyses.

Special Mobility Studies to Assess BART's Impacts on Disadvantaged Groups

These special mobility studies are specifically designed to address the questions outlined in Exhibit 10. When studying any phenomenon with social survey techniques, it is generally advisable to utilize different approaches to the same subject matter. This is frequently necessary when dealing with disadvantaged groups (particularly ethnic minority and low-income populations) in the relatively politically sophisticated urban settings of post-1968 America. First of all, the filling out of questionnaires is an activity that is more acceptable and more a "part of the culture" of middle income groups than of lower income groups and the unemployed. There is an initial tendency, then, for the latter to be under-represented in such surveys, and the overlap between socio-economic status and race/ethnicity has already been identified.[16] Secondly, even when control for income is accomplished, ethnic minorities--particularly Blacks and Chicanos--are more likely to treat the questionnaire not as a "neutral measuring instrument" but in political terms, either as an unwanted intrusion, or as data collected by those who have their own agenda and interests, quite apart from those of the minority communities. Thus, there is a measure of under-representation that is accounted for by the income and class bias, but there is a second measure that is explained by the increasing political self-consciousness of low-income residents and racial and ethnic minorities (which is not restricted to class). Therefore, as a political act, these groups might refuse to cooperate with (or attempt to sabotage) any such survey that came under the auspices of "neutral information gathering" for the general good.

In order to assess accurately the actual travel behavior upon which BART has had some impact, it will be necessary to supplement general survey devices with other investigation techniques that attend to these considerations. The above discussion suggests two related aspects of a solution. The first is the matter of access to persons who would be willing to respond if the instruments being used were more related to their typical cultural experiences. The second matter is the securing of confidence from respondents who might otherwise be hostile to the investigation. It is suggested that more small-scale, intimate, community-based studies be carried out, enlisting the assistance of members of these disadvantaged groups, indeed employing them, and honestly explaining the interests of the BART Impact Program.

A complementary set of five types of special mobility studies are planned to assess BART's impacts on six groups of disadvantaged residents; these include:

- Interviews with selected officials and line workers in organizations employing or serving one or more of the disadvantaged groups.

- Guided group discussions in local institutional settings with representatives of each of the disadvantaged groups.

- Interviews by trained urban ethnographers (1) with residents of neighborhoods where disadvantaged groups reside, (2) with representative users of BART who are members of disadvantaged groups, and (3) with the BART staff in the stations serving the neighborhoods where disadvantaged groups reside.

- Interviews by typical actors in the natural setting (1) with residents of neighborhoods where disadvantaged groups reside, and (2) with representative users of BART who are members of the disadvantaged groups.

- Specially structured surveys of a representative sample of respondents for a particular disadvantaged group. These will be designed so that generalizations will be possible on the perceptions, attitudes and travel behavior of the population as a whole of each disadvantaged group. The samples will be stratified so that a reasonable number of interviews are obtained for households where a member uses BART regularly and for households where a member could reasonably be expected to regularly use BART as an alternative but does not.

Measurement of Aggregate Travel Patterns

As discussed in Chapter II, the major impacts of BART on the transportation system and on travel behavior have been, or will be, manifested in changes in the total flows of traffic on the facilities of the highway and transit systems. Consequently, it is important that highway traffic volumes and transit ridership be carefully monitored during the course of the TSTB Project.

The methods that are proposed for monitoring BART and bus ridership and highway traffic volumes are briefly discussed in this section; a more detailed description is provided in the detailed research plan.[4]

Transit Ridership. The primary focus of this effort will be to acquire transit count data from available secondary sources, principally the transit operating organizations. The principal information available from each of the transit operating organizations is:

- BART
  - Faregate counts at each station for each Wednesday
  - Total daily system ridership and revenue
- AC Transit
  - Daily ridership on each route
  - Total daily ridership
  - Transbay daily ridership
- MUNI
  - Total daily ridership
  - Quarterly total passengers
- Greyhound
  - Ridership on each departure on every day

Accurate estimates of transit travel across the Bay Bridge screenline are available from counts conducted annually by the Institute of Transportation and Traffic Engineering in both April and October. Although additional traffic counting activities are conducted by the operating transit agencies, this work is largely conducted for special purposes and does not provide the basis for a time series analysis of transit traffic patterns.

The transit ridership information described above will be routinely obtained by the TSTB Project from the transit operating agencies. A description of each of the data items to be obtained and the arrangements which have been made with the transit operating agencies is provided elsewhere.[21]

Automobile Traffic Counts. Two principal historical traffic count data bases are available for the Bay Area: (1) the traffic count data acquired by MTC as part of the BART Impact Program, and (2) traffic count data obtained by the California Department of Transportation (CALTRANS) as part of its ongoing activities. The MTC traffic counting program was explicitly designed to assess BART's impacts on traffic volumes at critical screenlines in key traffic corridors in the BART impact area. A map showing the location of the screenlines utilized in the MTC traffic counting program is presented in Exhibit 15. Pre-BART traffic counts, including volume counts, automobile occupancy counts, transit occupancy counts, and vehicle classification counts have been collected by MTC at locations along the 12 screenlines and six BART station cordons indicated in the exhibit. Post-BART (but pretransbay) traffic counts have also been collected by MTC at seven screenlines and six BART station cordons. The traffic count data of MTC are the best pretransbay data available to the project and attempts will be made to use these data fully.

CALTRANS (District 4 and Toll Bridge Administration) also maintains a sizable file of traffic count data. CALTRANS operates two stations which are maintained on a year-round basis and for which extensive historical data are available: (1) Bay Bridge and (2) the Caldecott Tunnel. CALTRANS also has stations where counts are conducted for about two weeks at three- to four-year intervals; a map showing the locations of the permanent count stations which CALTRANS maintains in the Bay Area is presented in Exhibit 16. The permanent traffic count stations are mainly located on freeways, with relatively few locations on the principal arterials. The major advantage of using data from the permanent count stations maintained by CALTRANS is that pre-BART data are available for an extended historical period. This makes it possible to examine historical trends in traffic volumes at the selected locations for a period of from 10 to 20 years and to evaluate the hypotheses of whether BART has significantly modified these trends. The limitations of this experimental design relate principally to the quality of the historical traffic count data that are available. While the traffic counting procedures used by CALTRANS are sufficient for the purposes of that organization, the detail may not be sufficient for the purposes of testing hypotheses relating to BART's impacts on traffic volumes.

EXHIBIT 15
LOCATIONS OF MTC TRAFFIC COUNTING SCREENLINES

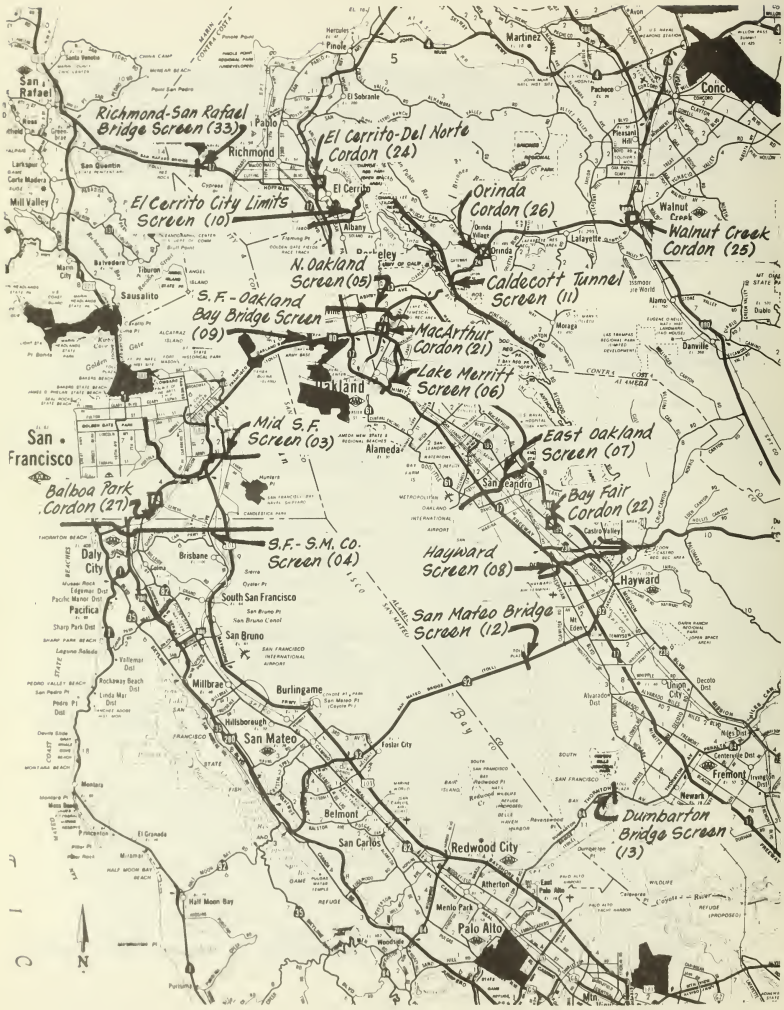
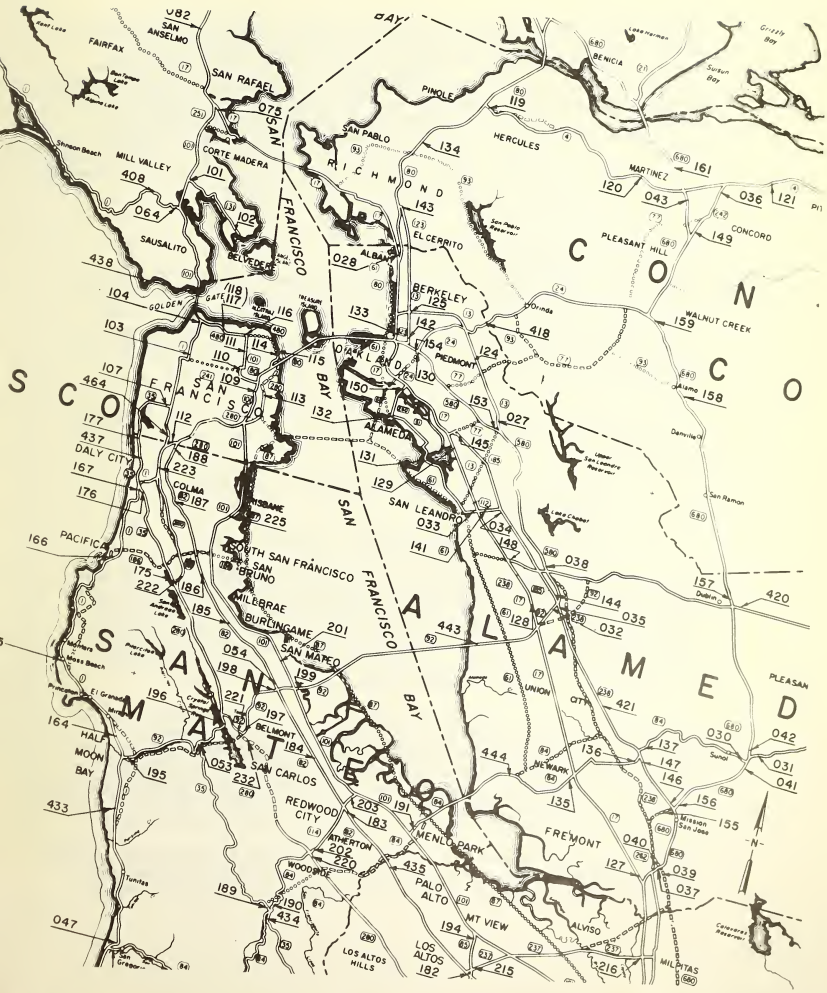


EXHIBIT 16
CALTRANS PERMANENT TRAFFIC COUNT LOCATIONS



The traffic counting program of the TSTB Project will focus on continuous 24-hour machine counts with subtotals recorded at 15-minute intervals (or six-minute intervals where the "before" data were recorded at this interval). These counts will be obtained at both the MTC and the CALTRANS stations on the major radial freeways and arterials with respect to the CBDs of San Francisco and Oakland in both the East and West Bays. In addition, traffic counts will be conducted on the four major bridges across the Bay. Finally, traffic counts will be obtained for the principal access streets to the six BART stations where "before" counts were obtained in the MTC traffic counting program.

Measurement of Traffic Congestion

Assessment of BART's impacts upon traffic congestion is one of the most important questions which will be examined in the TSTB Project. Three measures of traffic congestion will be used: (1) travel times on the major freeways in the BART corridors, (2) traffic accidents on these freeways, and (3) the time period during which the traffic metering system on the westbound lanes of the Bay Bridge is in operation.

Measurement of Travel Time. Pre-BART service travel time data for various locations within the BART impact area have been acquired using two methods:

- Moving car observer runs conducted by CALTRANS and reduced by MTC
- License plate matching studies conducted by MTC

The moving car observer runs were conducted by CALTRANS as part of that organization's ongoing monitoring of highway operations in the Bay Area. MTC had previously reviewed the complete CALTRANS files of travel time data and selected those elements in the data base describing conditions within the BART impact area. These data--which were in the form of tachographs--were carefully reduced by MTC to obtain accurate estimates of travel times between selected control points.

The travel time data produced by MTC's license matching survey is more selective. The survey was only performed for peak hour traffic on Route 24 between Walnut Creek and Oakland. Further, MTC encountered some difficulties in using the available computer algorithm for reducing the data. MTC believes, however, that it is possible to appropriately modify the computer algorithm for matching the license plates so that this approach would provide a valuable mechanism for obtaining travel time data.

Although it may be possible to design and implement a high quality license plate matching methodology for obtaining travel time data, it appears desirable to use the same methodology for obtaining the post-BART service

measurements as was used to obtain the pre-BART service measurements. For this reason, the moving car method will be the principal method for obtaining travel time data in the TSTB Project. The TSTB Project will also investigate the use of the license plate matching method as an approach to obtaining travel time data. The existing computer algorithm for conducting the license plate matching will be reviewed and development of an algorithm which provides more reliable results will be undertaken, if warranted.

If a new license plate matching algorithm is developed, exploratory travel time studies using this method will be completed and the results compared to the travel times obtained using a moving car method. If the results of these exploratory studies indicate that the license plate matching method provides a more reliable mechanism for obtaining travel time data at a lower cost than the moving car method, increased reliance will be placed upon the license plate matching approach during the remainder of the TSTB Project.

The design of the travel time measurement program for the remainder of the TSTB Project will largely depend on the types of "before" data available. The freeway sections to be monitored or surveyed will be compatible with those surveyed in the past and will either closely parallel BART corridors or lead to the Bay Bridge.

The number of travel time observations required will be on the order of 50 runs on each selected freeway section every six months. Morning peak hour runs will be conducted between 6:00 a.m. and 9:30 a.m. on Tuesdays, Wednesdays, and Thurydays at 15-minute intervals. Evening peak hour runs will be conducted on the same days of the week at the same headways between 3:30 p.m. and 7:00 p.m. This will allow four to eight data points in each half-hour period of analysis. The checkpoints to be used on the routes will be based on the checkpoints utilized in the tachograph runs previously conducted by CALTRANS, although some checkpoints may be eliminated to simplify the field recording of the data. Care will be taken to ensure that runs will not be conducted on days adjacent to holiday weekends or under bad weather conditions. In addition, data collection will, as far as possible, be coordinated with other monitoring activities, particularly traffic counts.

Measurement of Accidents. The California Highway Patrol maintains accident reports for all of the freeways in the Bay Area. These reports, and appropriate summaries thereof, will be periodically obtained by the TSTB Project from the California Highway Patrol and the information will be further summarized as necessary by highway segment.

Bay Bridge Metering System. The Bay Bridge metering system which is operational on the Bay Bridge immediately to the west of the toll plaza is used to control traffic leaving the toll plaza to reduce incidents associated with the merging of traffic from the 17 lanes of the toll plaza to the five lanes which are available on the Bridge. The metering system is only operational during peak periods of traffic congestion and is actuated based on the level of traffic congestion. Hence, the hours during which the metering system is in operation is an excellent indication of traffic congestion on the Bridge; this information will be obtained periodically from the Toll Bridge Administration and analyzed during the course of the TSTB Project.

VIII. SCOPE OF TRANSPORTATION SYSTEM AND TRANSPORTATION BEHAVIOR PROJECT SUBPROJECTS

The research methods of the TSTB Project will be implemented through a series of seven subprojects:

I Transportation System Description

II Network Formulation

III Accessibility and Mobility Analyses

IV Travel Behavior and Attitudes Assessment

V Travel Models Evaluation and Development

VI Assessment of BART Impacts

VII Assessment of BART Policy Issues

The timing of these subprojects within the three-year program of the TSTB Project is illustrated in Exhibit 17. During Phase I, extending from May 1974 through July 1975, the TSTB Project will focus on Subprojects I, II, and IV with exploratory studies in Subprojects III and V. During the remainder of the program, the TSTB Project will be involved in all of the subprojects with a particular emphasis on the last two during the latter stages.

This chapter briefly describes the scope of each of these subprojects during the entire three-year TSTB Project. For each phase of the Project, work plans have been, and will be, prepared to describe the tasks contained in each of the subprojects, the timing of the tasks, and the budgets allocated to each task.[22] The organization of the research methods into these seven subprojects is admittedly somewhat arbitrary; alternative specifications of the subprojects are possible with appropriate restructuring of the task content of the various subprojects.

Subproject I--Transportation System Description

This subproject incorporates those elements of the TSTB Project pertaining to the measurement of BART's impacts on the attributes of the transportation system and the physical measurement of the impedances that travelers encounter in using the transportation system. Specification of which attributes and which impedances of the transportation system will be measured was provided in Chapter VII; this section briefly considers the various major sets of tasks to be undertaken to complete this measurement program.

Exhibit 17

TIME PHASING OF TSTB SUBPROJECTS

Subproject Number	Subproject Description	1974 Summer	1974 Fall	1975 Winter	1975 Spring	1975 Summer	1975 Fall	1976 Winter	1976 Spring	1976 Summer	1976 Fall	1977 Winter	1977 Spring	1977 Summer	1977 Fall
I	Transportation System Description		—	—	—	—	—	—	—	—	—				
II	Network Formulation		—	—	—		—	—	—						
III	Accessibility and Mobility Analyses				—	—	—	—	—	—	—				
IV	Travel Behavior and Attitudes Assessment	—	—	—	—	—	—	—	—	—	—	—			
V	Travel Models Evaluation and Development				—		—			—	—	—			
VI	Assessment of BART Impacts				—			—	—	—	—	—	—	—	
VII	Assessment of BART Policy Issues				—			—	—	—	—	—	—	—	

Transportation System Monitoring. A significant volume of data on the attributes, impedances, and ridership for the various transportation modes in the Bay Area is available in the files of the various transportation operating and planning organizations. The transportation system monitoring task, which will be undertaken in the TSTB Project to obtain these data, is summarized in Exhibit 18. The 20 categories of data that will be obtained are indicated as the columns in this exhibit, and the 17 data sources constitute the rows. An "x" in a cell indicates that a particular item of data is available from the given source and the circle around the "x" indicates that these data will be routinely obtained as part of the transportation system monitoring effort of the TSTB Project. Other available data will, of course, be accessible as necessary for the purposes of the TSTB Project.

Field Measurements. In some cases, the physical measurements desired by the TSTB Project are not available in the files of an operating or planning agency in the Bay Area, and hence, field measurements will be required. These field measurements could take many forms, depending on the particular impedance which will be measured. For example, special studies would be needed to measure the air quality, noise, and smoothness of the ride in transit vehicles. Observational studies might be required, for example, to assess the cleanliness of transit vehciles or stations.

To the extent feasible within available resources, the transportation system monitoring activity will include the acquisition of appropriate data on the reliability, safety, security, seat availability, and parking availability for the transit and highway facilities in the BART impact area on an ongoing basis. Thus, data will be available on what are believed to be the most important of the augmented measures of transportation service, when efforts are undertaken to develop network representations of the transportation system for use in calibrating and applying travel behavior prediction models.

Travel Time Measurement. The travel time measurement program of the TSTB Project was discussed in Chapter VII. Field studies of travel times will be undertaken using either the moving car method or the license plate matching method (if this method can be usefully employed) at appropriate periodic intervals. The "before" and "after" travel time runs will be compared using appropriate statistical techniques.

Cost Analyses. This task will obtain cost data for both BART and other travel modes within the BART impact area for use in the analyses of benefits and costs which were discussed in the preceding chapter. The principal focus of the analysis will be on BART costs, particularly the engineering, construction, and preoperational testing (ECT) costs. The operating costs of BART and the parameters affecting this cost (including energy and labor parameters) will be considered. Most of the BART ECT cost data are available in historical files; those elements of the system which remain to be completed--including the Embarcadero Station in San Francisco, delivery of the remainder of the initial complement of 450 cars, and completion of preoperational testing--can

Exhibit 18

TRANSPORTATION SYSTEM MONITORING

	DATA SOURCES \ DATA CATEGORIES	Auto Occupancy	BART Feeder	BART Parking	Fare	Fuel Consumption	Highway Service	Operating Cost	Physical Characteristics	Revenue	Safety/ Security	Schedule Adherence	Schedule Frequency	Station Changes	Traffic Volume	Transfer	Transit Ridership	Transit Route	Transit Service	Travel Time/ Speed	Vehicle Classification
TRANSIT	AC Transit		x		x			x	x	x		x	x	x		x	x	x		x		
TRANSIT	BART		x	x	x			x	x	x	x	x		x		x	x	x	x	x		
TRANSIT	California Public Utility Commission				x								x					x				
TRANSIT	MUNI-BART Coordinated Transit Planning Project																x					
TRANSIT	Northgate Transit Company												x					x				
TRANSIT	Peerless Stages				x								x					x				
TRANSIT	San Francisco Municipal Railway (MUNI)				x			x	x	x		x	x	x			x	x		x		
TRANSIT	Southern Pacific Railroad				x								x				x	x				
TRANSIT	Santa Clara County Transit District Transit Service				x								x					x				
TRANSIT	Walnut Creek Downtown Shuttle Bus				x								x					x				
TRANSIT	Western Greyhound lines											x	x				x	x				
HIGHWAY	Alameda County Department of Public Works														x							
HIGHWAY	California State Department of Transportation						x								x					x		
HIGHWAY	California Toll Bridge Administration													x	x							
HIGHWAY	Contra Costa County Department of Public Works								x						x		x					
PLANNING	Metropolitan Transportation Commission	x													x		x			x	x	
PLANNING	Institute of Traffic and Transportation Engineering (ITTE)	x													x		x				x	

x - Data Available

(x) - Data Collected on a Continuing Basis

be estimated relatively accurately. Significant problems may be encountered, however, in determining the costs of particular design features incorporated in the BART system. These include, for example, the incremental costs associated with the art in the stations, the passenger amenities in the transit vehicle (carpeting, tinted windows, comfortable seats, air conditioning), and the facilities provided for the handicapped. Detailed cost analyses of specific elements may have to be conducted in order to assess the relative costs associated with particular design features.

Determining BART operational costs will be a major effort of this task. As the system will not be in full, stable operation until 1976 at the earliest, actual costs to date may not clearly reflect the operating costs of a stable system. Therefore, a certain degree of cost estimating must be performed. Engineering cost estimates will be made in conjunction with statistical estimates for as many elements of operational costs as possible. Cost parameters will be determined to allow for the projection of costs under various operating conditions.

The determination of the operating costs for non-BART modes will be derived as much as possible from secondary sources.* Cost estimates will be prepared for the non-BART modes included in the analysis of the various BART and no-BART alternatives.

Energy Analyses. This effort will identify the specific energy consumptions of the major transportation services in the BART impact area and report the findings in a manner that facilitates the evaluation of BART's impacts on the region's energy resources. These transportation modes are BART, the automobile, AC Transit's motor coaches, and MUNI's motor coaches, trolley coaches, and streetcars. Particular emphasis will be placed on BART's energy consumption, its components, and the variables that may affect it.

The BART energy analysis will focus on an extension and refinement of a major previous study of BART's energy consumption.[23] This analysis was based on data from June 1973, an early stage in BART's operational implementation when full-system capabilities were not available and BART was operating at a relatively low level. Consequently, the TSTB Project will apply the methodologies developed in this prior work to current energy data supplied by BART in order to assess the validity of the previous conclusions concerning propulsion and nonpropulsion traction energy, station energy, and maintenance energy. This analysis will be used to develop a model for predicting BART's energy consumption at various levels of system operation.

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*The University of California, Berkeley, has recently completed a cost analysis project which compares the costs of the various urban transportation modes in a study for the National Science Foundation. The results of this University of California study will be used to the maximum extent feasible by the TSTB Project.

The energy analysis to assess the energy consumption of AC Transit vehicles, MUNI vehicles, and the automobile will be based on a review of data and results available from various secondary sources. The energy consumption paramenters estimated for these modes will be substantiated by developing corroborating estimates from other sources. Relatively aggregate energy consumption estimates will be presented, in contrast to the more detailed work that will be prepared for the BART system.

The product of this effort will be the determination of a specific amount of energy consumption for all major modes of ground transportation within the three counties served by BART. In addition, actual and projected total systemwide BART energy consumption, including station and maintenance energy, will be presented. These results will later be utilized to determine the energy impact of the BART system on the region and the energy implications of BART as compared with the various no-BART alternatives.

Subproject II--Network Formulation

Two types of networks will be developed in the TSTB Project: (1) conventional networks incorporating distance, travel speed, travel time, and transit fare variables and (2) augmented networks incorporating selected additional measures of the level of service provided by the transportation system (e.g., reliability, security, safety, seat availability). These networks will represent the BART and no-BART alternative(s). This subproject includes specification of the no-BART alternative(s) utilizing the generalized no-BART alternative description previously determined.

Conventional Networks. The following set of highway and transit networks will be delineated in the TSTB Project:

PRE-BART

1. 1971 Highway Network

2. 1971 Transit Network

POST-BART

3. 1976 Highway Network (as it will exist)

4. 1976 Transit Network (including BART)

5. 1976 Highway Network (as it most likely would have existed if BART had not been implemented)

6. 1976 Transit Network (as it most likely would have existed if BART had not been implemented)

The year 1971 has been selected to represent the pre-BART condition in the Bay Area, inasmuch as BART service was first introduced in 1972 on the Fremont Line. Also, several major pre-BART service surveys were performed in 1971 which will be used during the TSTB Project; these include: (1) the Bay Area Survey (BAS-I) and (2) the Attitude and Awareness Survey performed by BARTD. The year 1976 will represent the post-BART condition because major post-BART surveys will be conducted by the TSTB Project in spring 1976. At this time, BART's schedule for incremental service improvements including reduced headways, direct Richmond to Daly City service, evening service, and weekend service is uncertain. The impact these improvements will have on the coding of the networks pertains to the headways which are coded for the BART routes as well as the provision for a direct Richmond to Daly City service.

MTC has developed a system of 440 regional traffic zones which give a finer level of detail on areas served by BART than the previously used zonal system. Therefore, they offer better network sensitivity to BART service. In choosing a zonal system for the TSTB Project, there is a trade-off between providing enough detail and yet minimizing the number of zones to reduce computing time. The effect of changing the zone system and still retaining compatibility with other data bases utilized by MTC and the TSTB Project must also be considered. Ideally, the TSTB Project should use the 440-zone system within the BART impact area. Outside this area, combinations of the 440 zones could be used. However, the savings in processing time that would be achieved by aggregating zones would be offset by additional network development work and lack of compatibility with the MTC data base. Therefore, the 440-zone system will be used so that the TSTB network will be directly compatible with the others maintained by MTC.

Specification of the No-BART Alternative. A "Generalized No-BART Alternative" (GNBA) is currently being developed for MTC by another contractor.[19]

In order to code a network to represent the no-BART alternative, it will be necessary in the TSTB Project to describe further the location and level of service of the transit and highway facilities identified in the GNBA, although design details for the no-BART alternative (NBA) will not be required. The TSTB Project will further define the description of the GNBA through reviews of reports in agency files as well as discussions with knowledgeable individuals. Based on the reviews performed to date, it appears that significant information on specific GNBA transportation facilities is available from preliminary feasibility and design studies that are in various agency files.

Augmented Networks. Augmented networks are essentially conventional networks modified to incorporate additional measures of the level of service provided by the transportation facility. Important augmented measures which might be utilized in the TSTB Project include reliability, security, safety, and seat availability. These augmented networks will be used in the TSTB

Project for two purposes: (1) to develop estimates of the relative transportation service for use in travel models development and the application of these models to various comparisons of the BART and no-BART alternatives, and (2) to assess the changes in the level of transit service provided to the region as a result of the introduction of BART service in terms of these augmented measures. This latter objective is of particular importance in assessing the change in service for BART travelers who previously used bus.

The augmented networks of the TSTB Project will be specifically related to the analysis desired. Thus, in all likelihood, the augmented networks will be developed for subareas of the region or specific travel corridors, rather than for the full, regional 440-zone system. Specification of the variables to be included in the augmented networks will be based on an analysis of the perceptual and attitudinal survey data acquired during Phase I of the TSTB Project. Methodologies for measuring the levels of the augmented measures of the modes operating within the BART impact area will also be determined.

Subproject III--Accessibility and Mobility Analyses

Accessibility Analyses. These analyses will be used in the TSTB Project to compare the impedances of BART to the impedances of the transit system prior to BART and the impedances of the various no-BART alternatives. Accessibility comparisons of the pre-BART and post-BART situations will also be used in the experimental design of the various analyses to identify the areas where it is believed BART has the greatest impacts.

Since the TSTB Project is primarily interested in the accessibility of various important population and travel market segments to various selected destinations, regionwide accessibility indices will not be prepared. Important population groups are defined in terms of income, ethnic identification, sex, age, and automobile availability; these travel market segments are defined in Exhibit 11. The types of destinations that are of particular concern include work facilities, shopping facilities, health facilities, educational facilities, recreational facilities, and social service organizations. The accessibility indices which are developed for these traveler groups and destinations will be weighted by (1) the actual number of trips between the two locations in a particular year and (2) the potential for travel between the locations as measured using activity and relative trip probability interchange information. By comparing the accessibility estimates for these various population groups and market segments to the selected destinations, it is possible to assess the relative improvement in accessibility provided by BART as compared to the pre-BART condition, the various no-BART options, and the highway system.

Initially, accessibility analyses will be performed using conventional networks and travel time and travel cost impedances. After the augmented networks are developed, additional accessibility analyses utilizing the augmented networks will be performed for the same population groups, market segments, and selected destinations.

The rationale behind and organization of an integrated program of five types of mobility studies is presented in Chapter VII. The special groups mobility analysis conducted in Phase I of the TSTB Project will focus on two disadvantaged groups--ethnic minorities and the physically handicapped--in an exploratory study to identify BART's impacts upon these groups and to further refine the initial questions presented in Exhibit 10. This initial investigation will include (1) interviews with selected officials and line workers in organizations serving these two disadvantaged groups, (2) guided group discussions in local institutional settings with representatives of these two disadvantaged groups, and (3) interviews by trained urban ethnographers with conspicuous ethnic minority users of BART. During the remainder of the TSTB Project, the special groups mobility analyses will be expanded to encompass other major disadvantaged groups (i.e., low-income residents, youth, elderly, and others with limited access to an automobile) and the other types of special groups mobility studies described in Chapter VII.

Subproject IV--Travel Behavior and Attitudes Assessment--Travel Data Assembly

This subproject involves the assembly of perceptual, attitudinal, and travel behavior data and highway traffic and transit ridership count data in accordance with the requirements specified in Chapter VII.

Survey Program. An integrated program of seven surveys is described in Chapter VII and summarized in Exhibit 14.

Transit Ridership and Highway Traffic Counts. An integrated program of transit ridership and highway traffic counts is described in Chapter VII.

Subproject V--Travel Models Evaluation and Development

This subproject is devoted to the development of models of travel behavior for use in explaining travel behavior responses to BART and for use in the transportation policy analyses to be conducted in the TSTB Project. As described in Chapter VI, two types of travel models will be developed in the TSTB Project: (1) behavioral models based on objectively measured impedance measures using logit type structures, and (2) behavioral models based on perceived impedance measures. Development of these travel models by the TSTB Project will be coordinated with the Travel Demand Forecasting Project currently being conducted by the University of California and MTC's continuing travel model development work.

The data bases available for calibrating these models include the October 1974 en route BART, automobile, and bus questionnaire mailback survey, the work place survey, the BITS surveys, and the home interview impedance tradeoff survey. The impedance data required to calibrate the first type of model will be obtained from the augmented networks developed in Subproject II.

Extensive sensitivity analyses will be conducted using the developed models to assess the relationship between BART's patronage and BART's design features. The models will also be used to assess passenger traveler behavior responses to the various no-BART alternatives.

Subproject VI--Assessment of BART Impacts

This subproject involves an extensive series of statistical analyses of the impacts of BART with respect to each class of questions identified in Chapter III:

- Changes in the attributes of the transportation system
- Changes in the impedances for automobile travel, both perceptually and physically measured
- Changes in the impedances for bus travel, both perceptually and physically measured
- Changes in traveler attitudes
- Changes in traveler perceptions
- Changes in travel behavior
- Changes in travel patterns
- Highway congestion changes
- Secondary travel behavior changes
- Changes in the attitudes, perceptions, and behavior of disadvantaged groups

One of the principal themes of the analysis will be to distinguish between those changes which simply occurred concurrent with BART and those which can be attributed to the introduction of BART. This will be approached through the use of the quasi-experimental designs described in Chapter V. Many of these experimental designs involve extensive use of the travel perceptions, attitudes, and behavior data as well as the traffic and transit ridership count data which were collected by MTC prior to the initiation of the TSTB Project. In particular, the following data from periods prior to or during interim stages of BART operation will be analyzed in this subproject: (1) the Bay Area Survey I (BAS-I); (2) the BARTD Attitude and Awareness Survey, Waves I and II; (3) the BART Impact Travel Survey (BITS-I); and (4) the vehicle and person count data developed by MTC and CALTRANS.

Subproject VII--Assessment of BART Policy Issues

There are three classes of policy issues to be considered in the TSTB Project which will require further analysis beyond the evaluation analyses conducted in Subproject VI; these are:

- The technology assessment issue of the costs and benefits of BART as compared to one or more no-BART alternatives.
- The technology design issue of the benefits and costs of the various BART design features.
- The equity issue of which groups within the population benefit from BART and which pay the costs for constructing, implementing, and operating BART.

Analyses of benefits and costs will be developed in Subproject VII insofar as they are within the scope of the TSTB Project. MTC will undertake an overall assessment of the costs and benefits of BART, based on the results of all of the BART Impact Program projects. A discussion of the TSTB Project's approach to each of these three policy analysis issues is presented in Chapter VI.

IX. INTEGRATION AND COORDINATION OF TRANSPORTATION SYSTEM

This chapter briefly discusses the integration and coordination of the TSTB Project research with: (1) other projects of the BART Impact Program, (2) related research efforts focused on the BART impact study area, (3) other Bay Area transportation planning activities, and (4) other impact assessment studies.

Relationships To Other BART Impact Program Projects

A brief description of the other major projects within the BART Impact Program was provided in Chapter I. Whereas the TSTB and Environment Projects began in spring 1974, the remaining projects will not begin until spring 1975. The extent to which the various survey activities of the TSTB Project can be integrated with those of other projects can only be determined after final research plans and work plans have been completed for these other projects.

Because of its central role, the TSTB Project relates in some fashion to all of the other projects in the BART Impact Program. In most cases, the TSTB Project provides data to these projects. In other cases, the TSTB Project requires data from these projects, particularly with respect to the assessment of the policy issues associated with BART. A very general discussion of the interrelationships between the TSTB Project and other BART Impact Program projects is presented in the Strategic Plan.[24]

Environment Project. The most important output of the TSTB Project used by the Environment Project is a description of travel patterns (particularly highway travel patterns) for use in the air pollution and noise studies conducted by the Environment Project. In addition, the TSTB Project's description of the attributes of the transit and highway systems will be used by the Environment Project. The TSTB Project requires inputs from the Environmental Project on the impacts of the various no-BART and BART technologies, as well as the various BART design features, on the environmental elements being assessed by this project. Inasmuch as both projects are investigating the energy impacts of BART, careful coordination of this work will be required between the two projects.

Land Use and Urban Development Project. The principal outputs of the TSTB Project which will be used by the Land Use and Urban Development Project are the descriptions of the transportation system for use in land use modeling. Descriptions of the activity system from the TSTB Project's surveys will be used in assessing BART's impacts on particular local areas. The TSTB Project requires inputs from the Land Use and Urban Development Project on forecasts of the distribution of activity within the Bay Area for future time periods for use in the accessibility analyses and the comparison of the BART and no-BART alternatives.

Economics and Finance Project. Outputs of the TSTB Project required by the Economics and Finance Project include information on the improvement in minority group participation in the work force resulting from BART and cost data for the no-BART alternative. The TSTB Project requires inputs from the Economics and Finance Project on the incidence of the taxation required to finance the community contribution for BART. This information is required for the assessment of the equity issues associated with BART.

Institutions and Life Styles Project. The principal outputs of the TSTB Project desired by the Institutions and Life Styles Project are detailed information from the various surveys conducted in the TSTB Project regarding: (1) the respondent, (2) the respondent's trips, (3) the trips which are not made by the respondent, (4) actual and potential trip perceptions of the respondent, and (5) other members of the household.[25,26] The list of data items which the Institutions and Life Styles Project is requesting be incorporated in the TSTB Project surveys is extremely lengthy. Careful consideration will be given to incorporating as many of these items as possible consistent with the overall objectives of the survey as well as the resource constraints of the TSTB Project.

Public Policy Project. The principal input to the TSTB Project from the Public Policy Project is a detailed articulation of the public policy issues pertinent to the impacts of BART on the transportation system and travel behavior. These issues should be articulated from the perspective of decision-makers at the federal, state, and local levels. To ensure that the results of the TSTB Project are transferable to other metropolitan areas, it would be desirable if these policy analysis objectives are articulated for both the Bay Area and other metropolitan areas, and for both transit operating and transit planning organizations.

No-BART Alternative Project. The TSTB Project provided the No-BART Alternative Project with an initial specification of the costs of each of the potential elements of the no-BART alternative. The principal outputs of the major input to the TSTB Project from the No-BART Alternative Project is a specification of the generalized no-BART alternative and a decision history of BART.

Relationships to Other Research Activities Within the BART Impact Area

There are two major studies of transportation services in the BART impact area which are currently under way: (1) the Travel Demand Forecasting Project conducted by the Institute of Transportation and Traffic Engineering, University of California, Berkeley, and directed by Professor Daniel McFadden; and (2) the Comparative Costs of Transportation Modes Study conducted by the Institute for Urban and Regional Development, University of California, Berkeley, and directed by Professor Theodore Keeler. The University is currently completing the Cost Analysis Project, and hence, the major opportunity

for coordination between the two projects is for the TSTB Project to utilize the reports and the data bases assembled by the Cost Analysis Project for the TSTB Project's cost analyses.

There are major opportunities for coordination and cooperation between the TSTB Project and the Travel Demand Forecasting Project; many of these opportunities have been described elsewhere.[27,28,29] In general, the Travel Demand Forecasting Project desires extensive outputs from the TSTB Project on travel behavior and impedance data for use in calibrating a disaggregated model of home-to-work modal choice behavior. The major output of the Travel Demand Forecasting Project that is potentially usable by the TSTB Project is the work modal split model which might, depending on its specification, be usable in the various policy analyses of the TSTB Project. Continuing coordination between the TSTB Project and the Travel Demand Forecasting Project is being accomplished by MTC. The TSTB Project will provide the desired data inputs to the Travel Demand Forecasting Project to as great an extent as possible consistent with the overall research program and resource constraints of the TSTB Project.

Coordination with Other Bay Area Transportation Planning Activities

Both MTC and other transit planning and operating organizations have a variety of other transportation planning activities under way. MTC is maintaining a general coordination effort with these other transportation planning activities. This coordination effort includes the transmittal of TSTB working materials (e.g., proposed survey designs, proposed transportation system monitoring activities, proposed 1976 transit networks) to these organizations for review and comment and the transmittal of the products of the TSTB Project (particularly data) on an as-needed basis.

Comparison of Findings with Other Impact Assessment Studies

To ensure the transferability of TSTB Project findings to other metropolitan areas, MTC has initiated discussions with transit planning and operating organizations in other metropolitan areas contemplating or implementing rail rapid transit to determine their views regarding the crucial policy issues, early products, and general information which need to be derived from the BART Impact Program. In particular, arrangements have already been established with the Washington Metropolitan Area Transit Authority (WMATA) and the Metropolitan Atlanta Regional Transit Authority (MARTA).

The U.S. Department of Transportation has requested that the findings of the TSTB Project on BART's impacts be compared to the findings of other transit impact studies. Very few major transit facilities have been implemented in the United States in the last decade which are even partially comparable to BART. Based on a review of the transit projects which have been implemented and a consideration of what impact studies have been accomplished for these projects, it was decided that where possible, the results of the TSTB Project

would be compared to the results of the impact studies of the following transit projects:

- Lindenwold High-Speed Rail Line--a radial rail line serving the New Jersey suburbs of Philadelphia.[30,31]

- South Shore Line--a radial rail line serving the southern suburbs of Boston.[32]

- Shirley Highway Express Bus Project--an exclusive lane for express buses serving the Virginia suburbs of Washington, D.C.[33,34,35,36]

- San Bernardino Express Bus Project--an exclusive bus lane serving the San Bernardino Valley suburbs of Los Angeles.[37]

Reports of the impact studies of these four transit facilities are or will be obtained and will be used wherever possible to compare the findings of the TSTB Project to the findings of these other impact studies. In addition, the findings of the TSTB Project will be compared to those of impact studies of major transit improvements in Canada (particularly the Toronto and Montreal transit systems) and Europe.

Appendix A

DESCRIPTION OF THE BART SYSTEM

Appendix A

DESCRIPTION OF THE BART SYSTEM

Service Area and Routes

The entire 71-mile, 34-station BART system lies within the three Bay Area Counties of San Francisco, Alameda, and Contra Costa. Within these three counties the system traverses portions of 14 cities, as well as a number of unincorporated areas (Exhibit A-1). Based on the 1970 census, the population of the cities traversed is 2,414,169, which is approximately 75% of the central Bay Area counties (Alameda, Contra Costa, Marin, San Francisco, San Mateo) population of 3,109,519. About 500,000 people are employed in San Francisco County, and about 610,000 are employed in Alameda and Contra Costa Counties; thus the three counties served by BART have 80% of the total employment of 1,390,000 in the five central Bay Area counties.

Approximately 16 of the 71 route-miles and 14 of the 34 stations are underground, 3 route-miles and no stations are in rock tunnel, 4 route-miles are in the Transbay Tube, 23 route-miles and 13 stations are on aerial structure, and 25 route-miles and 7 stations are at grade. In addition, 4 miles of subway were constructed for the San Francisco Municipal Railway light rail services in connection with the construction of BART.

The four principal BART lines are essentially radial with respect to the central business districts (CBDs) of San Francisco and Oakland. The Daly City Line, linking San Francisco to Oakland, is 12 miles long and contains 9 stations. It is composed of 3 segments: A 4-mile transbay segment consisting of the Transbay Tube; a 2-mile San Francisco CBD segment containing 4 stations (1 of which, the Embarcadero Station, is not open as of the date of this report); and a 6-mile southwestern San Francisco segment which has 5 stations. The remaining 3 lines emanate from the Central Oakland section of BART which contains 7 route-miles and 5 stations.

The Concord Line, including its tunnel through the Berkeley Hills is made up of 18 route-miles and contains 6 stations serving the rapidly growing residential communities of Orinda, Lafayette, Walnut Creek, and Concord in eastern Contra Costa County. The Fremont Line is made up of 24 route-miles of track and contains 8 stations in the southern Alameda County cities of southern Oakland, San Leandro, Hayward, Union City, and Fremont. The Richmond Line contains 16 route-miles and 6 stations in the cities of Berkeley, El Cerrito, and Richmond.

BART Services

BART trains have a maximum design speed of 80 miles per hour; the average speed for trips on the system is estimated as 38 miles per hour. In full-system operation, the East Bay services (Fremont, Richmond, and Concord to San Francisco and Richmond-Fremont) will have headways of 6 minutes during

Exhibit A-1

POLITICAL JURISDICTIONS TRAVERSED BY BART

Jurisdiction	Population[a]	Miles
Albany	14,674	1.2
Berkeley	116,716	3.7
Fremont	100,869	2.6
Hayward	93,058	6.2
Oakland	361,561	18.2
San Leandro	68,698	3.6
Union City	14,700	2.2
Concord	85,164	2.9
El Cerrito	25,190	2.8
Lafayette	20,484	4.5
Richmond	79,043	2.0
Walnut Creek	39,844	2.8
Daly City[b]	66,922	0.2
San Francisco[c]	715,674	10.8
Remainder of Counties[d]	611,572	7.3
Total	2,414,169	71.0

a. Estimates provided by 1970 U.S. Census.
b. In San Mateo County.
c. City and County of San Francisco.
d. Alameda and Contra Costa Counties only.

peak hours, 12 minutes during off-peak day hours, and 20 minutes during evening hours. The West Bay service (between Daly City, San Francisco, and West Oakland) will, in full operation, have headways of 2 minutes in peak hours, 4 minutes in off-peak day hours, and 20 minutes during evening hours.

Service on BART has been incrementally introduced:

- September 12, 1972--opening of the Fremont Line
- January 29, 1973--opening of Richmond Line
- May 21, 1973--opening of Concord Line
- November 5, 1973--opening of Daly City Line
- September 16, 1974--initiation of Transbay BART service

Presently, three BART services (Fremont-Daly City, Concord-Daly City, and Richmond-Fremont*) are in 14-hour-a-day, 5-day-a-week operation with 12-minute headways during peak periods. Incremental service improvements which are planned during the remainder of 1975 and 1976 include extending the hours of operation to 20-hour-a-day service, providing weekend service, providing nontransfer Richmond-Daly City service, and reducing the headways to the design levels. Trains vary in length according to the time of day, with a maximum train length of nine cars (with a corresponding capacity of about 650 seated passengers).

Access Services

The principal access modes to BART are public transportation (particularly bus), automobile, and walking. About 18 of the 25 East Bay BART stations are located within the AC Transit service area, and AC Transit provides extensive feeder bus services. Other feeder bus services are being provided or planned for the remaining 7 East Bay BART stations. Similarly, feeder bus service is being provided or is planned for the West Bay stations.

A total of about 17,400 parking spaces are available at 22 BART stations. The capacity of individual parking facilities ranges from 240 to 1,400 spaces. Most of the parking facilities are provided on the East Bay lines--6,800 spaces on the Fremont Line, 5,900 spaces on the Concord Line, and 3,800 spaces on the Richmond Line. Daly City is the only station on the Daly City Line with parking facilities; the existing 900-space facility is currently being expanded to 1,700 spaces. There are 11 stations which do not have parking facilities: 7 are in the downtown areas of San Francisco, Oakland, and Berkeley, which are destinations for many BART riders and where development of parking facilities would be difficult; 8 of the 11 are in San Francisco, where City policy prohibited development of BART parking.

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*Passengers traveling from Daly City and San Francisco to stations on the Richmond Line are required to transfer in Oakland to trains running on the third service of the current BART system between Fremont and Richmond.

BART Patronage

Various planning estimates have projected that during its first year of full-system operation, BART would serve approximately 200,000 passengers per day, 80,000 of whom would be transbay users. As shown in Exhibit A-2, the addition of the transbay link to the BART system has given rise to a very large increase in total system ridership. Before the start of transbay service, BART ridership averaged about 70,000 trips per day on the San Francisco and East Bay Lines. Including the transbay link, system ridership has climbed to over 120,000 trips per day; transbay ridership thus accounts for about 43% of total BART system ridership. About 77,000 or 62% of the average daily ridership is served in the a.m. and p.m. peak-hour periods. It should be emphasized, however, that these patronage estimates are for what is still a traditional period of BART operation.

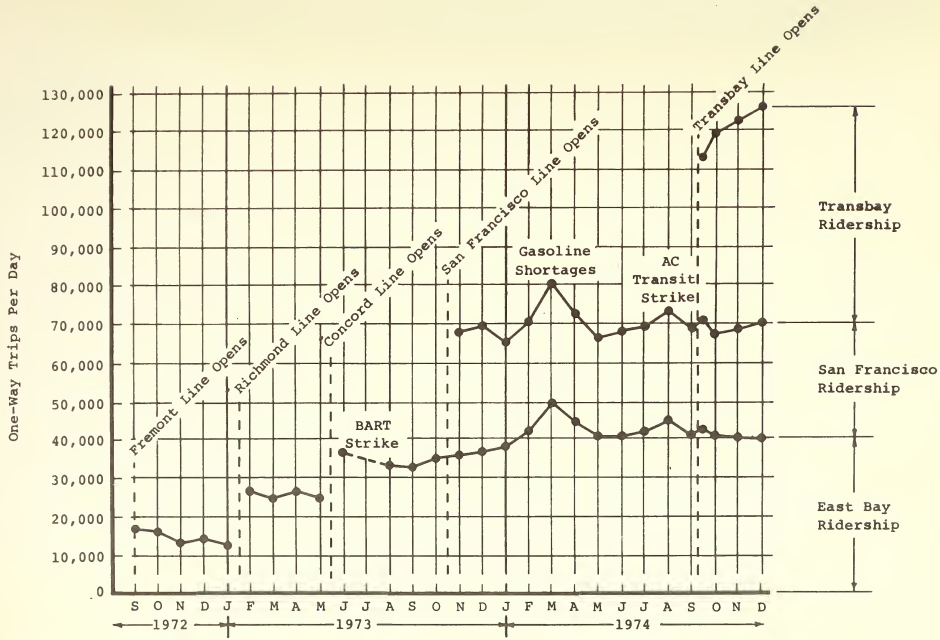

EXHIBIT A-2

AVERAGE DAILY BART RIDERSHIP, SEPTEMBER 1972 - DECEMBER 1974

Source: • BARTD Office of Research, BART Monthly Patronage Reports

Appendix B

IMPORTANT IMPEDANCES FOR WHICH BART IS EXPECTED TO INDUCE CHANGES

Appendix B

IMPORTANT IMPEDANCES FOR WHICH BART IS EXPECTED TO INDUCE CHANGES

1. Total door-to-door travel time
2. Time spent walking
3. Time spent waiting as a result of schedule delay
4. Out-of-pocket cost of travel (in the short run)
5. Total cost of travel (in the long run)
6. Effort involved in transferring between vehicles
7. Reliability of on-time arrival (in normal circumstances)
8. Reliability of on-time arrival (in abnormal circumstances)
9. Comfort of the vehicle seat and surroundings
10. Security from personal attack or unpleasantness
11. Safety from vehicular accidents
12. Flexibility of being able to combine secondary trip purposes
13. Flexibility of accommodating unusual times for the return trip
14. Crowding of the vehicle
15. Availability of seats
16. Probability of a prolonged cessation of service (e.g., a transit strike)
17. Parking availability
18. Privacy and the ability to avoid undesirable social contact
19. Ability to read the paper or work
20. Ability to listen to the radio, sleep, sightsee
21. Freedom to smoke
22. Noise level within the vehicle
23. Smoothness of the ride (e.g., vibration level within the vehicle)
24. Protection from the weather
25. Aggrevations of driving in congested traffic conditions
26. Vehicle decor and cleanliness
27. Air quality and temperature within the vehicle
28. Method of payment for transportation service
29. Station decor and cleanliness
30. Identification with travel environment and other travelers

Appendix C

LIST OF REFERENCES

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